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Construction series

THEIR CHARACTERISTICS AND USE

By

PREVOST HUBBARD

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Cut-Back Asphalts—Their Characteristics and Use

By PREVOST HUBBARD
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No other type of asphalt product has increased in production and use during the last few years as rapidly as has cut-back asphalt. During 1929, about 130,000 tons of cut-back asphalt was used in the United States mainly for highway purposes. In 1930, the quantity increased to nearly 262,000 tons or over 100 per cent and in 1931, the total amounted to over 466,000 tons, 70 per cent more than for 1930 and nearly $3\frac{1}{2}$ times as much as in 1929. The present year will undoubtedly show a further material increase.

Petroleum refining is primarily a process of distillation by means of which various constituents of the crude oil are separated from each other. Two general classes of products are produced by this process—distillates and residuals. Distillates are the lighter and more volatile constituents which are vaporized, and recovered by condensation in a coil or cooling chamber. Residuals are products which do not distill over during the process but are left behind in the distilling apparatus. If a relatively small quantity of distillate is removed the resulting residual is quite liquid. As more distillate is removed, the residual becomes more viscous until eventually an asphalt cement remains in the distilling apparatus.

In the broadest sense, cut-backs are manufactured products, composed of residuals which have been fluxed or blended with distillates of similar origin. Cut-back asphalts are therefore asphalt cements fluxed to any desired viscosity with distillates produced in refining petroleum. They thus differ from the ordinary fluxed asphalt which is an asphalt fluxed or blended with a liquid residual oil. Sometimes liquid residual oils are combined with distillates in order to reduce the viscosity of the former. While such products are cut-backs, they are not cut-back asphalts for the reason that the base which

was fluxed with the distillate is not an asphalt cement. In addition to the three classes of fluxed products already mentioned, there is a fourth which may be termed blended oils. These are mixtures of two or more liquid residuals.

In order that there may be no misconception regarding these four classes of products, they may be summarized as follows:

1. Cut-back asphalt = asphalt cement + petroleum distillate.
2. Cut-back residual oil = residual oil + petroleum distillate.
3. Fluxed asphalt = asphalt + residual oil (flux).
4. Blended oil = residual oil + residual oil.

It is the first class only which will be discussed in this paper.

General Characteristics of Cut-Back Asphalts

The function of the distillate in a cut-back asphalt should be to temporarily liquefy the asphalt cement so as to facilitate its application and manipulation in highway treatment and construction. It is thus a substitute for heat which could be used to render the asphalt liquid prior to use. For certain types of work, however, it is more useful than heat because its liquefying effect extends over a longer period of time. Eventually, however, it should separate from the mixture leaving an asphalt cement in place as a bonding and waterproofing medium. The distillate should therefore be of a type which will be volatilized or otherwise removed after it has served the purpose for which it was used. Heavy non-volatile distillates can be employed in the preparation of cut-back asphalts to render the asphalt liquid, but

such products resemble liquid residuals in their non-hardening or extremely slow hardening characteristics. Relatively light volatile distillates are therefore used in the manufacture of cut-back asphalts.

The degree of fluidity of a cut-back asphalt is largely a function of the amount of distillate used in its preparation. The more distillate present the more liquid becomes the final product. With a large amount of any light distillate an asphalt cement may be fluxed to almost water-thin consistency. With lesser amounts more viscous products are obtained of any desired consistency. In general, the harder the original asphalt cement, or the lower its penetration, the greater will be the quantity of a given distillate required to bring it to a given degree of fluidity. However, a marked difference is often found in the liquefying capacity of a given distillate for asphalts, of the same penetration obtained from different sources or produced by different processes, so that the amount of distillate present cannot be too intimately associated with the viscosity of the finished product. Failure to recognize this fact has, in some cases, been responsible for the development of specifications in which the relations between viscosity requirements, percentage of distillate recovered by test, and penetration of the recovered asphalt, have been so close as to eliminate many products which would be entirely satisfactory for the intended use.

There is another factor connected with the liquefying capacity of distillates for asphalt cements that should be noted, namely, that the heavier or less volatile the distillate the more of it will be required to bring an asphalt cement of given penetration to a given degree of fluidity. The most desirable range in fluidity which cut-backs should possess depends upon factors which will be discussed under the uses to which these materials are put. This characteristic is determined by means of a viscosity test with the Furol Viscosimeter, the temperature of test usually being 77° F., 122° F., or 140° F., depending upon whether the product is very liquid or very viscous.

The hardening characteristics of cut-back asphalts or the rapidity with which

they may be expected to revert to an asphalt cement, after application or use, depends upon the amount and character of the distillate which is present and upon conditions attending their use. The more volatile the distillate the more rapid will be the rate of hardening, other conditions being the same. However, the rate of hardening is also governed by the amount of distillate present, those containing a large amount of distillate hardening more slowly than those containing a smaller amount. Thus, when made from the same constituents the more fluid products, under normal atmospheric conditions, require a longer time to revert to an asphalt cement than do the more viscous products.

Manufacture of Cut-Back Asphalts

In the refining of petroleum, it has already been pointed out that two classes of products are formed, distillates and residuals. In the initial process the distillate fraction is separated into a number of grades, according to their respective boiling point ranges. These fractions are then further refined, frequently by redistillation and chemical treatment, to produce finished distillate products, such as gasoline, kerosene, various grades of furnace oil, heavy distillate fuel oil, gas oils and lubricants. In the original distillation of the crude petroleum, sharp divisions between the fractions insofar as their boiling points are concerned, cannot be made. The reason for this is that the entire distillate is made up of a great number of individual hydrocarbons with a gradation in boiling points running from the lowest temperature to the highest temperature of distillation, and a certain amount of heavy distillate is carried over with the lower boiling hydrocarbons.

Redistillation and chemical treatment adds considerably to the expense of finished products and in the manufacture of cut-backs, it is often more economical for the refiner to use unfinished distillates than those which have been manufactured to an exact and narrow range of boiling points. Even the carefully manufactured finished products usually contain traces of heavier distillates. Provided the presence of these heavy distillates is recognized and

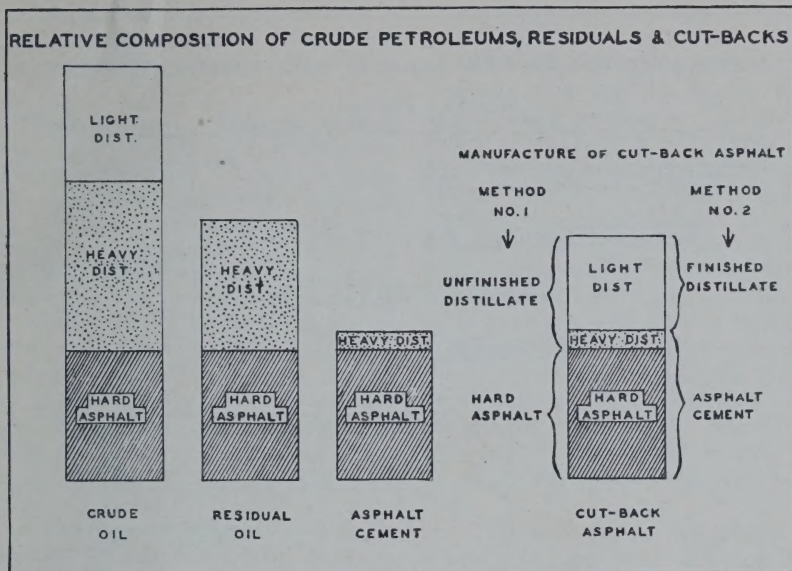


Figure 1

properly cared for by the selection of an asphalt of suitable penetration, a cut-back, produced with an unfinished distillate, is just as satisfactory and less costly than one produced with a finished distillate.

Asphalt cement may be considered as a combination of very hard asphalt with heavy distillate. The more distillate present the softer will be the asphalt cement. If a soft asphalt cement is subjected to distillation and a portion of this distillate removed, the asphalt cement becomes harder. These heavy distillates do not volatilize at normal temperature. It is evident, therefore, that two cut-back asphalts of the same general characteristics may be produced, one from a relatively soft asphalt with a finished light distillate containing no heavy ends, and the other from a harder asphalt with a light unfinished distillate containing a small percentage of heavy ends. In the first case practically the entire distillate may be expected to volatilize, leaving the original asphalt cement, while in the second case, all but the heavy ends of the distillate may be expected to volatilize leaving the original hard asphalt permanently softened to the same consistency as the base used in the first instance. This example is graphically illustrated in

the right-hand diagram of Figure 1, which also shows the relationships which have been developed between crude oil, residual oil, asphalt cement and cut-back asphalt. From the above, it is evident that specifications for cut-backs should not attempt to cover the characteristics of the original constituents as such requirements may unnecessarily restrict the producer, raise manufacturing costs and tend to eliminate desirable competition, without in any way bettering the product.

The approximate boiling point ranges of various finished distillates are shown in Figure 2. It will be seen that there is considerable overlapping in the constituents present in the various grades. The first four grades are classed as light distillates and, in an unfinished state, are commonly used in the preparation of cut-back asphalts. The other grades, classed as heavy distillates, would not ordinarily be used for this purpose except as certain of their fractions might be present to a limited extent in the light products.

Value of Distillation Test for Cut-Backs

The hardening characteristics of a cut-back asphalt are determined and specified by means of a distillation test, in which

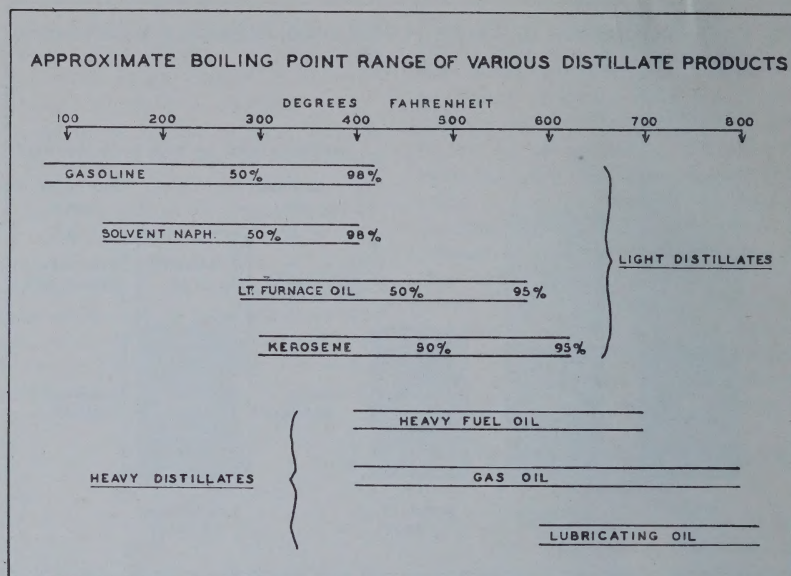


Figure 2

they are gradually heated to a maximum temperature of 680° F., after which the residue is removed from the distilling flask, allowed to cool and its penetration determined. It has been found that a temperature of 680° F. is necessary to remove by this method all but the last traces of a refined gasoline distillate which is known to evaporate from the product at normal air temperatures when the cut-back is distributed over a surface in a relatively thin film.

The test in general indicates, therefore, the character of base which may be expected to develop after use of the cut-back, provided the distillate is afforded an opportunity to leave it.

This characteristic is covered by specifying the desired penetration limits of residue obtained from the distillation test. From the foregoing discussion, however, it is evident that these limits need not apply to the penetration of the original asphalt used in manufacturing the cut-back.

The rate of hardening of the product is indicated by the proportion of the total distillate removed which comes off at certain lower temperatures which have been selected as a basis of comparison, such as

437° F. and 600° F., and specifications for cut-back asphalts frequently contain requirements for minimum or maximum percentages which should be recovered when the material is distilled to these temperatures.

Highway Uses of Cut-Back Asphalts

Cut-back asphalts are used for a variety of purposes in the treatment, construction and maintenance of highways, among which may be mentioned the following:

1. Priming road surfaces preparatory to surface treating, seal coating or constructing an asphaltic wearing course.
2. Surface treating and seal coating road surfaces to produce a thin asphaltic carpet with a cover coat of selected mineral aggregate.
3. Preparation of road-mixes with various types of mineral aggregate for the purpose of constructing wearing courses of substantial thickness.
4. Preparation of plant mixes with various aggregates, to be spread and compacted in an unheated con-

dition. Such mixtures are used in the construction of foundations and wearing courses and for cold patching.

The characteristics which the cut-back asphalt should possess will vary markedly with the purpose for which it is to be used, the character of mineral aggregate with which it is combined and the time in which it is expected to harden, also with the character of the final hardened product that it is desired to secure. The initial viscosity of the product is of paramount importance. For some purposes, it is necessary that the cut-back asphalt have an extremely low viscosity and for other purposes, that the viscosity be just as high as it can be made, and, at the same time, permit its admixture with the mineral aggregate with which it is to be combined. High viscosity is particularly important in connection with mixtures which are to be laid and compressed immediately after preparation.

Priming

The function of a primer is to so prepare an existing road surface as to make it adaptable for additional treatment. Primers are used mainly on waterbound types of surface, such as earth, sand-clay, gravel and macadam. All of these surfaces carry an appreciable amount of dust, or fine material, passing the 200-mesh sieve, which tends to repel viscous products rather than to absorb them. A primer should, therefore, be of low viscosity so that it will be readily and completely absorbed by the surface which is to be treated, after which it should harden so as to consolidate and assist in waterproofing the surface. While acting as a dust layer for dust which may be present, a primer is not essentially a dust-laying oil, nor should it be expected to serve as a binder for aggregate cover that may be later applied. A liquid non-volatile residual oil is usually more satisfactory to use from a purely dust-laying standpoint, and a much more viscous cut-back asphalt is more satisfactory to use as a binder for cover aggregate. It is, therefore, a mistake to attempt to produce a single material which will serve as a primer, as a dust-layer, and also as a binder.

For earth and sand-clay surfaces, the Furol Viscosity of a primer at 77° F. should preferably be lower than 150. It has been found that if a suitable distillate is used in its preparation, a viscosity between 40 and 150 at 77° F. will permit it to penetrate into an earth or sand-clay surface within twenty-four hours, and often within a shorter period. Gravel and macadam roads which do not carry such a high percentage of extremely fine material, absorb such a primer much more readily, usually within a few hours. It is therefore possible to utilize a product with a somewhat higher viscosity for such surfaces, although it is not essential to do so and for this reason, a primer having the viscosity limits above mentioned, can be successfully used for all types of surfaces.

It has been found that cut-back asphalts, produced with very volatile distillates or with distillates carrying a high percentage of very volatile hydro-carbons, will not penetrate a dense fine-grained surface no matter how low its viscosity may be. There are two reasons for this, the first being that the very light portion of the distillate volatilizes so rapidly after such cut-back has been applied that the viscosity of the product is raised to such an extent as to prevent penetration. The other reason is that the more volatile the distillate the less perfect its solvent action for the asphalt and the more readily will it separate from the asphalt by preferential absorption into the fine material of the road surface. The net result is that the asphalt in the cut-back is deposited on the surface rather than being carried into the surface. A type of distillate, comparatively free from the very light low boiling hydro-carbons, is much to be preferred, as it is an excellent solvent for the asphalt and readily carries it into the surface, after which the solvent separates to a large extent by preferential absorption into the fine material, leaving the dissolved asphalt deposited in the upper portion of the road and itself penetrating to a greater distance.

Within the last two years, a primer of this nature has been developed which has proven extremely satisfactory for the purpose, although prior to that time attempts

to utilize asphaltic products for priming were far from satisfactory because the character of the distillate which should be used in its preparation was not clearly understood.

The exact consistency of asphalt base left in the upper portion of the road surface is not of material consequence, and a primer which, upon distillation to 680° F., yields a residue with a penetration of less than 300, may be considered as satisfactory.

As previously stated, a primer should not be expected to hold a cover coat of aggregate because it should be completely absorbed into the road surface. Where the original road surface is well bonded, treatment with a primer, such as described, will hold the surface intact under traffic to a considerable extent without producing a sticky or tacky surface condition. It is not, however, to be recommended for use without some subsequent treatment of the surface with asphaltic material, except perhaps in the case of well drained and well consolidated earth roads. In this field, which has not as yet been thoroughly explored, it gives promise of producing satisfactory results without requiring the use of other asphaltic products as an adjunct.

Surface Treating and Seal Coating

Where the purpose of a surface treatment is to build up a thin waterproof bituminous carpet course with a light cover of mineral aggregate, the cut-back asphalt should cure or harden to a soft asphalt cement as rapidly as possible after application. Its distillate constituent should therefore be readily volatile. As has been pointed out, a product of this nature is not easily absorbed by a fine grained surface, and, if the surface is at all dusty, the deposited asphalt may not bond firmly to the road. For such surfaces an initial treatment with a primer is highly desirable and, in some cases, necessary. Such preliminary treatment completely bituminizes the road surface and insures a firm bond with the asphalt which is later used in the construction of the bituminous carpet. In the surface treatment of an old bituminous road, or one which has been

previously surface treated, use of the primer becomes unnecessary and should be eliminated if the road is first thoroughly cleaned.

The viscosity of the surface treating cut-back asphalt should be sufficiently low to permit of its ready application at almost any desired rate per square yard without preheating, by means of a pressure distributor. A viscosity of from 80 to 160 at 122° F. permits of such application in warm summer weather and only slight warming is required in cool weather. While a more viscous product of the same type would produce satisfactory results, the necessity of invariably preheating it largely offsets its inherent advantage as a cut-back, for the reason that a soft asphalt cement could be applied in a similar manner to equal advantage. The cut-back for surface treatment, when subjected to the distillation test, should yield an asphalt with a penetration preferably between 60 and 120. Such a product, shortly after application, leaves a residue upon the road surface which will firmly cement together a cover of stone chips or gravel free from dust.

Mineral Aggregates for Road or Plant Mixing

The characteristics of cut-back asphalt, suitable for the construction of wearing courses of substantial thickness, vary considerably with the characteristics of the mineral aggregate which is selected for use. Whether or not the aggregate contains an appreciable amount of dust or fine particles passing the 200-mesh sieve is the most important consideration.

Two well defined road-mix and plant-mix types of construction have been developed during recent years in which the mineral aggregates are sharply defined. In one of these, which has been termed the macadam aggregate type, practically no 200-mesh material is present and in fact nearly all of the aggregate is retained on the $\frac{1}{4}$ inch screen. For such a product, commonly known as clean crushed rock, a quick curing cut-back asphalt of suitable viscosity should be used.

In the other, known as the graded aggregate type, a substantial percentage of 200-mesh particles is present, usually speci-

fied as between .7 and 14 per cent. There is also a relatively high percentage of sand or particles passing the 10-mesh and retained on the 200-mesh. With such an aggregate, mainly because of the presence of 200-mesh particles, a quick curing cut-back asphalt will not readily mix and troublesome balling is likely to occur if it is used. This is due to the same basic considerations which have been discussed in connection with primers. The type of cut-back best suited for such an aggregate is therefore similar to a primer but of considerably higher viscosity. In other words, the distillate which is present in the cut-back should be comparatively free from very light low-boiling hydro-carbons.

Between these two distinctive types of aggregates that have been pretty well standardized, there are a great variety of gradings found in material deposits which, in many cases, can undoubtedly be used to advantage in road-mix or plant-mix construction for light traffic. This field has as yet been explored to only a limited extent. There are, however, a few fundamental considerations that should govern the selection of a cut-back for use with any aggregate.

1. The original viscosity of the cut-back should be as high as will permit of the production of a uniform mixture by the method which is to be used.
2. For coarse open aggregates which contain little or no material passing a $\frac{3}{4}$ inch screen, a quick curing cut-back should preferably be used.
3. For fine open aggregates which contain little or no 200-mesh particles but a high percentage passing the $\frac{3}{4}$ inch screen, a medium curing cut-back of relatively high viscosity is frequently most suitable.
4. For close graded aggregates or those which contain an appreciable percentage of 200-mesh particles, a medium curing cut-back is required.
5. Other things being equal, the finer the aggregate or the smaller the average diameter of particle, the

lower must be the viscosity of the cut-back unless the aggregate is heated prior to mixing.

- For mixes with a coarse open aggregate,
6. For plant-mixing with any given aggregate, a more viscous cut-back should be used than for road-mixing.

Open Aggregate Mixtures

such as the macadam aggregate type, it is desirable to build up on the individual particles, as thick a film of asphalt as possible. When the mixture is made on the road this usually requires at least two applications of the cut-back with an interval of mixing which permits the first application to harden and cure by volatilization of its lighter constituents. Repeated light applications of a quick curing cut-back asphalt of very low viscosity may be made to produce the desired result, but it is more economical and efficient to use one of just as high viscosity as can be conveniently mixed by the road-blade or other road mixing device. With the exception that the higher viscosity is produced by the presence of a smaller proportion of distillate, the type of cut-back is identical with that described for surface treatment.

For cool weather mixing or when the mixture is to be stock piled for cold patch work, a Furol Viscosity at 122° F. of from 200 to 400 is recommended. For construction in warm summer weather, it is advantageous to use a product with a Furol Viscosity at 140° F. of from 275 to 400. For cold laid plant mix construction, a Furol Viscosity at 140° F. of as high as 700 to 1400 is desirable. In all cases, the cut-back should be warmed before mixing, but preheating of the aggregate is unnecessary except sometimes for the purpose of drying it before use in the preparation of plant mixes. Aeration of the mix before it is compressed is essential to the development of asphalt coatings of high binding value when the original cut-back is of relatively low viscosity.

When the aggregate is practically free from 200-mesh particles, but has a high percentage of material passing the $\frac{3}{4}$ inch or 10-mesh sieve, selection of the best type and grade of cut-back becomes a matter

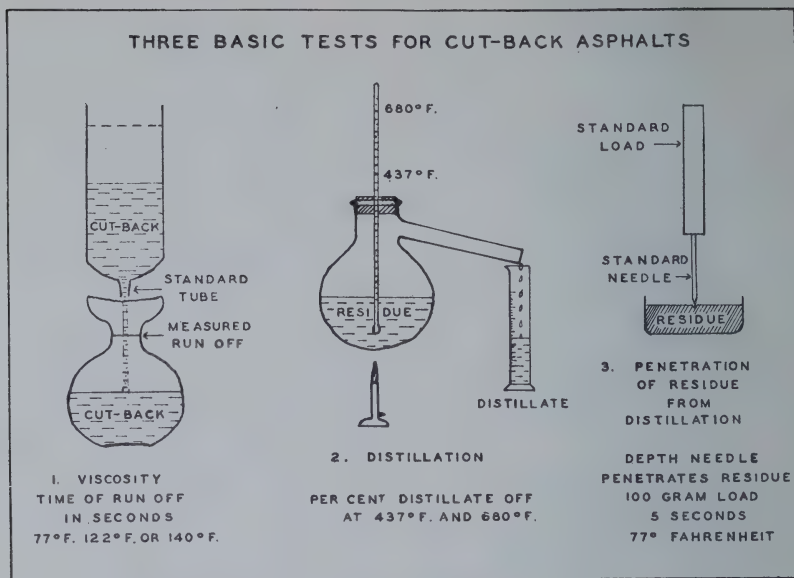


Figure 3

of judgment. If the aggregate has high inherent stability a quick curing cut-back, after warming, may sometimes be used to advantage in the preparation of plant mixes. For road-mix construction, however, and in all cases where it is expected that occasional blade maintenance may be required, a medium curing cut-back of relatively high viscosity is to be preferred.

Dense Graded Aggregate Mixtures

For practically all of the dense graded aggregates, which contain a relatively high percentage of 200-mesh particles, use of a medium curing cut-back asphalt is required for reasons that have already been set forth. Incomplete curing or hardening within the body of the mixture, when newly laid and consolidated, is desirable as it permits reworking and shaping by means of a blade if the original construction becomes rough or otherwise unsatisfactory. After admixture with the aggregate the asphaltic material should, however, become sufficiently viscous to resist displacement by water and should thoroughly waterproof the mixture itself.

For road-mix construction with this

type of aggregate, it is necessary that the original product be of lower viscosity than is desirable from a waterproofing standpoint, in order to facilitate the mixing operation. In cool weather a medium curing cut-back asphalt with a Furol Viscosity at 140°F. of from 150 to 250 may be used but in warm weather it is possible to satisfactorily manipulate one, with a viscosity at the same temperature of from 300 to 500, which is preferable. In plant-mix construction, one with a viscosity at 140°F. of from 500 to 800 may ordinarily be used. The percentage of 200-mesh material, however, has some bearing upon the most desirable range of viscosity and lower viscosity products must be used with high dust aggregates than with low dust aggregates.

While aeration of the mixture slowly increases the viscosity of the medium curing cut-back, preferential absorption of distillate by the 200-mesh material also plays an important part in curing. After compaction, which is usually affected by traffic, the medium curing cut-back at the surface hardens quickly to a soft asphalt cement to produce a waterproof seal. The curing process below the surface is, however, much more gradual and this is de-

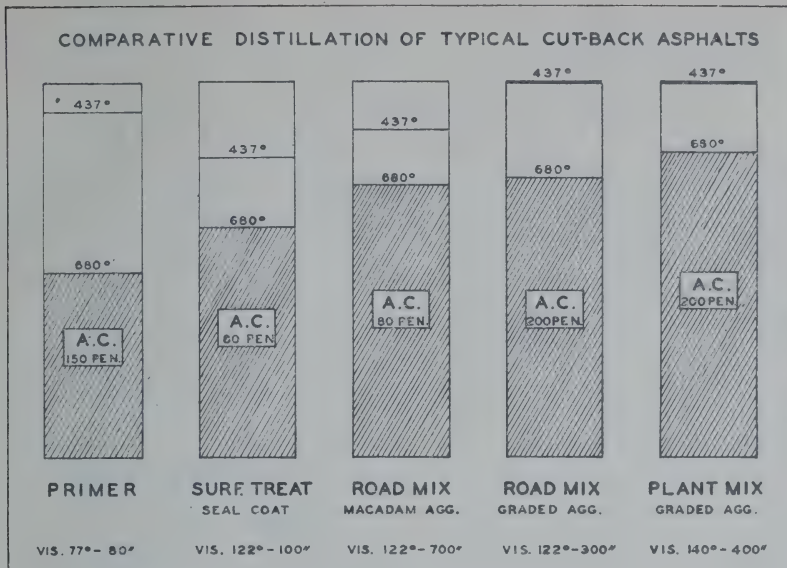


Figure 4

sirable for aggregates which are sufficiently dense and stable to produce, without a bituminous binder, what would ordinarily be considered as a good waterbound road.

For all of the medium curing cut-back asphalts used in road-mix or plant-mix construction, the residue from the distillation test should preferably show a penetration of from 100 to 300 at 77° F.

It is not the object of this paper to develop detailed specifications for cut-back asphalts but rather to describe variations

in their composition and characteristics as related to their various uses. From this discussion, it is evident that the fundamental tests which determine their suitability for a given use are first, original viscosity; second, character of distillate present; and third, consistency or penetration of residue obtained from distillation. These three tests are illustrated in Fig. 3 and characteristics of a few selected types and grades of cut-backs are shown in diagrammatic form in Fig. 4.

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Fundamental Physical Properties of Mineral Fillers—I

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A paper entitled "Some of the Fundamental Physical Characteristics of Mineral Fillers Intended for Asphalt Paving Mixtures" was presented at last year's meeting of the Association [Bib. 1]. Since then some of the methods for evaluating the physical characteristics of mineral powders have been further developed and improved. The advances made are presented in this paper which is a progress report of the Research Committee's Subcommittee on Fillers.

The properties of the individual particles composing a mineral powder which affect its value as a filler for bituminous materials are: (1) size and size distribution; (2) shape; and (3) texture. Dependent upon these properties of the particles are: (4) the surface area; and (5) the void content of the powder. These properties of the particles and of the powder will now be discussed individually.

(1) Particle Size and Size Distribution

The apparatus and method for the determination of size and size distribution of the particles in a powder have been described [Bib. 1]. Roller [Bib. 2] has further improved the apparatus and technic developed by him and has extended his study of particle size measurement with the air analyzer Fujii [Bib. 3] has also discussed the measurement of the particle size and distribution in cement by means of an air analyzer. Determinations of the particle size of very fine pigments such as carbon black and zinc oxide have been made by Gehman and Morris [Bib. 4] using a micro-turbidimeter.

During the past year the capacity and accuracy of the air analyzer have been increased by shortening the settling tubes; improving the contact between the air and the particles in the U-tube; adding properly designed spring tappers to the settling tubes; adding a 20-inch tube for removing particles less than five microns in diameter; and substituting highly

polished Allegheny metal for the brass tubes which had a tendency to become fouled. In addition, the apparatus has been so constructed that the 20-inch tube and one of the smaller tubes can be used simultaneously for the analyses of different samples. Keeping the temperature of the tubes above that of the entering air has increased both the speed and accuracy of the removal, especially of the finer particles which, being in the form of a fume, tend to precipitate upon a cold surface. Numerous minor matters of technic have been improved.

Figure 1 shows the flowmeters and manometers for regulating the flow of air to the apparatus. In Figure 2 a complete assembly of the apparatus including the five settling tubes can be seen, while in Figures 3 and 4 the arrangements of the U-tubes, tappers, etc., are shown in detail. When operating, the machine is enclosed in a sound-proof cabinet within which the temperature is maintained slightly above that of the air entering the machine.

Although the method of determining size and size distribution in mineral powders by this apparatus and the theory underlying it have been described previously, a brief resume will be given. Knowing the specific gravity of the mineral, the velocity of air needed in the cylindrical part of the settling tube to carry over the largest size particle in the desired fraction may be calculated by means of Stokes Law. The volume of air necessary to give this velocity is determined by the size of the settling tube. This calculated volume of air is delivered to the apparatus through flowmeters of the Venturi type. The air is cleaned and conditioned to constant humidity before entering the flowmeters. The velocity of the jet of air entering the U-tube and impinging upon the particles composing the powder is also important and is controlled by the size of nozzle used. Small particles require a higher jet velocity for separation and dispersion than do the larger. The lower cone of the settling tube is tapped rapidly to effect continu-

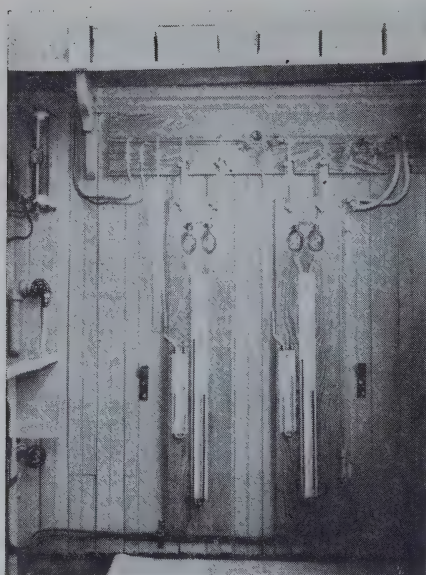


Figure 1

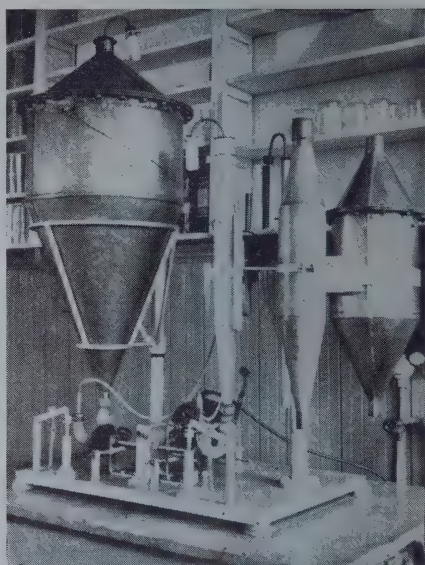


Figure 2

ous return of over-size material to the U-tube. The U-tube is tapped simultaneously and in such a fashion that the powder rolls over and over, constantly presenting a fresh surface to the jet of air. The particles of a diameter equal to or smaller than that used in the calculation involving Stokes Law are carried up by the rising current of air and collected in a weighed paper thimble. When microscopic examination shows that the particles passing from the settling tube are all of the same size and of the diameter desired, the fraction is considered to be completely removed. After all of a fraction is collected, the thimble and contents are weighed, and the weight per cent of the fraction in the powder calculated. The size distribution in a powder is determined by the weight per cent of the various fractions. Each fraction is thoroughly mixed and the size distribution in it determined by a microscopic

count and measurement of the dimensions of the particles.

The surface mean diameter of the unfractionated powder, used later to calculate the surface area, may be determined from the weight per cents and the mean particle diameters of the fractions. This is done as follows: The weight per cent of each fraction (W) is divided by its surface mean diameter in microns (d_s) (actual microscopic measurements on the fractions of a large number of different mineral powders have shown that the surface mean diameter of a fraction is approximately equal to the average of the size limits). The values of $\frac{W}{d_s}$ are added and the sum divided into 100, giving the surface mean diameter (d_s) of the unfractionated powder. These results, together with those on particle size and size distribution for a pure silica dust are given in Table I.

TABLE I

Size Limits (microns)	Surface Mean Diameter of fraction in microns (d_s)	Weight Per Cent (W)	$\frac{W}{d_s}$
—2	1.0	10.9	10.90
2—5	3.5	12.7	3.63
5—10	7.5	12.6	1.68
10—20	15.0	22.9	1.53
20—40	30.0	31.0	1.04
40—75	57.5	9.1	0.16
+75	100.0	0.8	0.01
		100.0	18.95

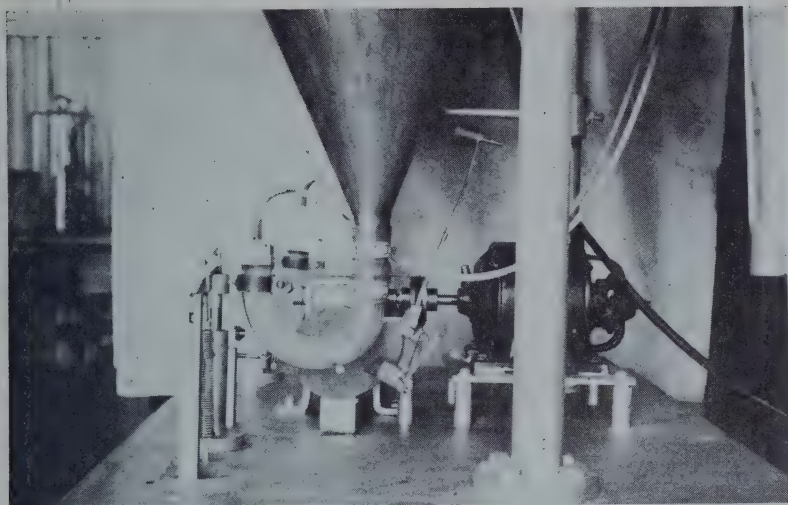


Figure 3

$$100$$

$$\frac{100}{18.95} = 5.25 \text{ microns} = d_s, \text{ the sur-}$$

face mean diameter of the unfractionated powder. Thus, the average particle diameter for this silica dust is 5.25 microns. For all of the powders we have investigated it has been found to be below ten microns. Clifford Richardson, years ago, made a careful examination of size and size distribution in commercial fillers utilizing the rate of sedimentation in water. He obtained average diameters of about 25 microns. Considering the deficiencies of the apparatus available at that time, it is not surprising that he obtained a high average diameter, though, of course, there is a possibility that a quarter of a century ago commercial dusts may not have contained so much of the extremely fine material found in present day powders.

The opening in a 400 mesh screen, which is the finest made at the present time, is a square 38 microns on a side. Of the seven fractions given above, five would be classified by screen analysis as passing a 400 mesh screen. Until the development of methods, such as that described above, little was known concerning the very important factor of size distribution within the finer portions of mineral powders. Data on the amounts of a powder retained on 200, 325 and 400 mesh screens, together with that

passing the finest, gives insufficient information concerning the particle size distribution in a powder. Thus, it can be seen that it is important for anyone using mineral powders as fillers to have at his command an apparatus for determining accurately the size and size distribution, especially in the finer fractions.

(2) Particle Shape

A good microscope is necessary for ascertaining the shapes of mineral particles. For the larger particles, direct observation through the microscope reveals in most cases all the necessary details. In the case of the finer particles it is advantageous to project the microscopic image on a screen, since the resulting magnification allows a more definite characterization of the particle shape than could be obtained by direct observation. When a permanent record is desired, a photomicrograph may be prepared.

Most minerals possess cleavage planes and when ground to a powder tend to split or break along these planes, thus giving a characteristic shape to the particles, though attrition may round off the edges to a certain extent. Figures 5 to 7 illustrate some of the differences in particle shape which may be encountered in commercial powders. These photomicrographs are all of particles in the 20 to 40 micron fractions, magnified 160 diam-

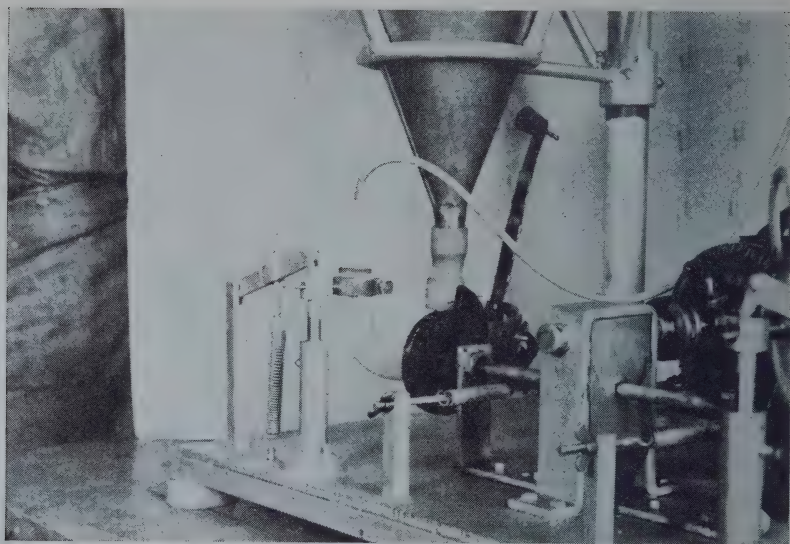


Figure 4

eters. Marble, as shown in Figure 5, is fairly regular in shape and possesses a relatively smooth surface. Less regularity in form and greater roughness of surface are shown by trap rock in Figure 6. This material is apparently non-homogeneous as is evidenced by the opacity of some of the particles and the translucence of others. Figure 7 presents slate particles which are the least uniform in shape we have encountered so far. The photomicrograph indicates that the surfaces of these particles are very rough.

(3) Particle Texture

Under the term "texture" we include not only the nature of the surface but also the physical condition throughout the particle. The surface may be smooth or rough; glass-like or matte; hard or soft. The particles themselves may be solid or filled with capillaries. If solid they may contain cracks or fissures to a varying degree. The determination of texture is exceedingly troublesome owing to the difficulty of measuring the numerous variables which comprise the property. Powders made up of particles which contain numerous capillaries, cracks, or fissures may present a much greater surface to a bitumen with which they are mixed than is indicated by particle size and size distribution. Thus, the absorption of bitumen on a mineral surface

may depend to a great extent upon the variables included in the property of particle texture.

(4) Surface Area of a Powder

The specific surface, which is the summation of the areas of all the particles present in one gram of powder, is an important property when the material is to be used as a filler for bituminous substances. In the preliminary report given last year, several methods of estimating surface area were discussed. Of these methods calculation from particle diameters is so far the most satisfactory when accurate data concerning particle size distribution in the powder is available. Consequently, the improvements which have been made in the determination of particle size distribution have resulted in a definite increase in the accuracy of estimation of surface area.

The specific surface or surface area per gram of a powder may be calculated from its surface mean diameter and specific gravity by the following equation:

$$(1) \quad S = \frac{6 \times W \times 10^2}{p \, dS}$$

where, S = surface area per gram of powder in square centimeters (specific surface);

W = weight per cent of fraction in the powder (in the case of the unfractionated powder, $W = 100$);

p = specific gravity of the mineral;

and dS = surface mean diameter of the particles in the powder.

The surface area of any size fraction

in a powder may be calculated from the above expression by substituting the corresponding values of W, p, and d_s. The summation of these results for all of the fractions gives the specific surface of the unfractionated powder. The values obtained in this way check very closely with those obtained by direct substitution of the values of W, p, and dS for the

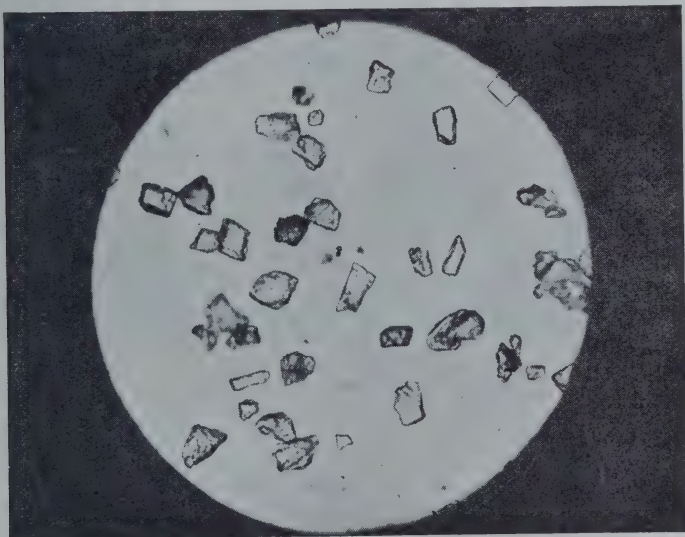


Figure 5

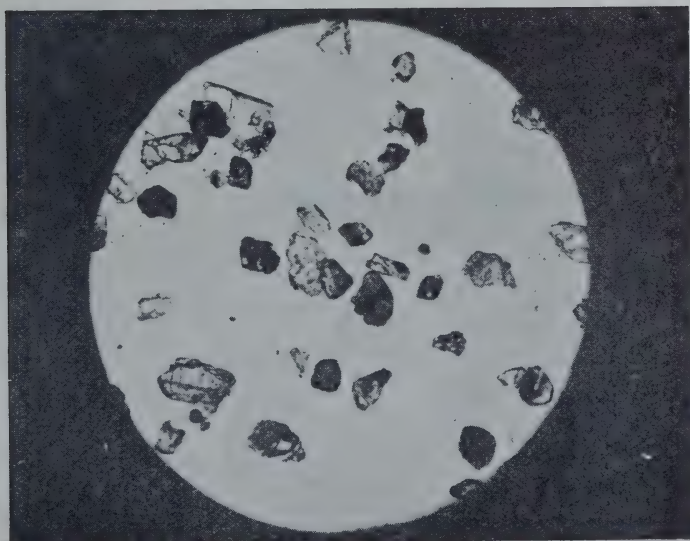


Figure 6



Figure 7

unfractionated powder in equation (1).

Table II shows the surface areas calculated for each size fraction of the silica dust mentioned above, and the specific surface of the unfractionated powder.

TABLE II

Size limits (microns)	Surface Area (sq. cms.)
—2	2510
2—5	832
5—10	395
10—20	342
20—40	236
40—75	36

Specific surface of unfractionated powder = 4351 sq. cms.

$$6 \times 100 \times 10^2$$

$$S = \frac{2.62 \times 5.25}{100} = 4364 \text{ sq. cms.}$$

The influence of texture on surface area is difficult to evaluate since rough surfaces, cracks, fissures and capillaries, all of which are difficult or impossible to estimate, are sources of inaccuracy due to the fact that they increase the amount of surface.

(5) Void Content of a Powder

The void content associated with different types of packing is an important

property for mineral powders to be used as fillers for bituminous materials. In addition to the dry compaction and liquid absorption methods described in the paper presented at the last meeting, a briquetting method similar to that of Norton and Hodgdon [Bib. 5] has been developed which, especially for fine powders, gives a void content associated with a more closely packed condition than that attained by the other two methods. The procedure used in our laboratory may be described as follows: a 0.5 per cent solution of high-grade glue in water is added to the powder in an amount just sufficient to thoroughly wet it. The wet mixture is worked into place in a steel mold which is equipped with a removable bottom and a close-fitting steel piston or plunger. After insertion of the piston a weight of about 25 lbs. per square inch is applied and rocked back and forth in order to set up vibrations in the wet mixture. Any excess solution is pressed from the material and drains from the mold. When drainage ceases the wet briquette is removed, placed in a cool oven and the temperature raised gradually to 105° C. and maintained at that temperature over night. The dried briquette is weighed and its dimensions determined. The volume of the briquette

is calculated, and knowing its weight the bulk density of the dry compacted powder may be computed. The void content is calculated by the following equation:

$$(2) \quad V = 100 - 100 \frac{B}{p};$$

where, V = percentage of voids in the dry compacted powder;

B = bulk density in grams per cubic centimeter;

and p = specific gravity of the mineral.

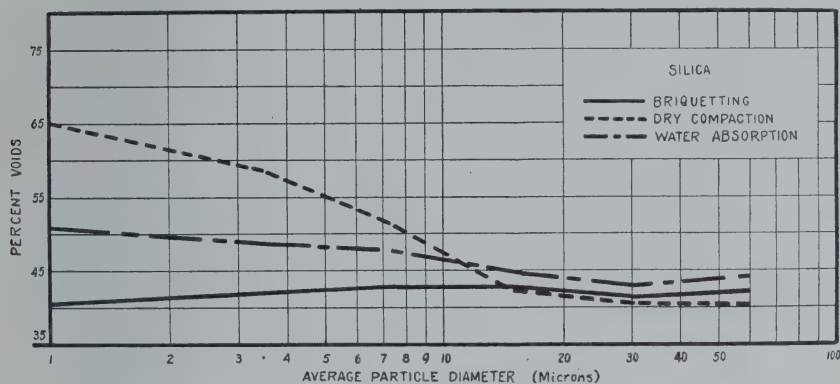


Figure 8

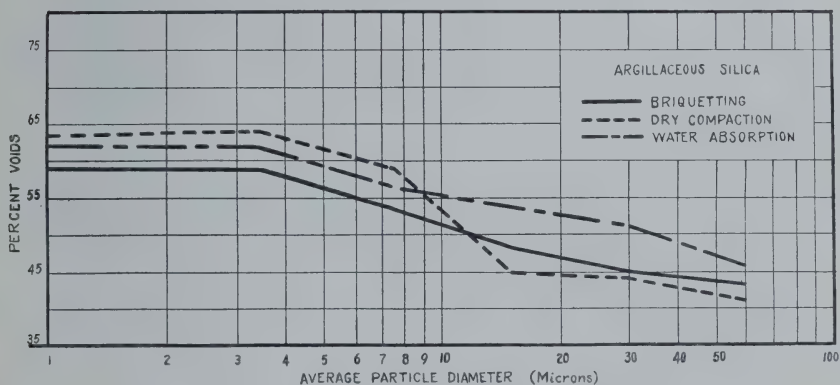


Figure 9

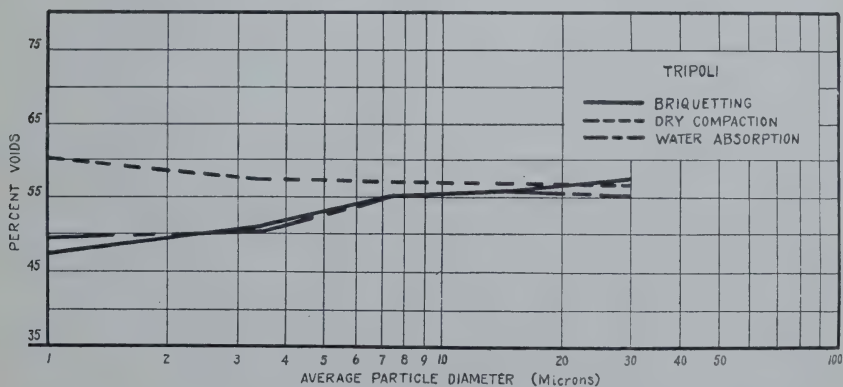


Figure 10

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While water was satisfactory for use with the finer fractions, briquettes made with the coarser powders tended to crumble when dried unless some adhesive was employed. The weight of the glue present is small in comparison to the weight of the dried briquette, and hence the error introduced is negligible. The use of such a solution makes possible the determination by this method of the void content of materials as coarse as sand.

Figures 8 to 10 show the void content as determined by the three methods on the pure silica mentioned above, an impure silica dust, and pulverized Tripoli, plotted against particle size. The particle size fractions used were prepared with a laboratory Federal Air Classifier. The size limits of the fractions used were minus 2, 2-5, 5-10, 10-20 and 20-40 microns. The diameters plotted in the figures are the arithmetic averages of the size limits.

For the finer fractions dry compaction gives void content values corresponding to a loose packed state, whereas, liquid absorption data indicate a more closely packed condition. The briquette method with the lowest values shows the closest packing attained experimentally with the finer fractions. For the larger particle sizes the values for the three methods more nearly approach each other.

In Figure 8 the void contents of the various size fractions of the pure silica dust, containing particles fairly regular in shape, are approximately the same when determined by the briquetting method. Several other powders investigated have shown this same relationship. Figure 9 shows the void content values of various size fractions of a silica dust which contains rather large quantities of clay. The soft argillaceous material is concentrated in the finer fractions and the harder silica in the coarser. In this powder there is an appreciable decrease in

void content as determined by all of the three methods with increase of particle size beyond the 2-5 micron fraction. Tripoli, shown in Figure 10, gives a definite increase in void content with increase in particle size. This is undoubtedly due to the difference in texture of the particles in the various size fractions. Tripoli is a silica which is filled with pores and capillaries and, as the particles are reduced in size, more and more of the capillary volume disappears. In the coarsest fractions the void content is composed of capillary and interstitial volume, whereas, in the finest fraction the void content is almost entirely due to interstices and consequently is smaller in amount. The void contents of the intermediate fractions are thus composed of interstitial and varying amounts of capillary space.

Conclusions

Although the properties of both individual particles and of mineral powders composed of them have been discussed separately, these properties are actually all more or less closely related and interdependent. For example, surface area is dependent upon all of the properties of the individual particles, whereas, void content is sometimes independent of size but always dependent upon size distribution, shape and texture.

It is possible that the shapes of the particles of some mineral powders vary with their size. That the texture may also change with change in particle size has been shown above.

For a satisfactory evaluation of a mineral powder, which is to be used as a filler for bitumen, it is essential that all of the properties discussed above be fully understood. The equally important problem of their effects on the characteristics of bituminous mortars may then be studied with greater possibility of obtaining fundamental information of practical value to the asphalt paving technologist.

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Estimation of Moisture in Cold Mixes

By A. R. EBBERTS

Technical Director, Colprovia Roads, Inc.

The estimation of moisture in cold bituminous paving mixtures is important because if disregarded, any moisture present may be eliminated with the bitumen in standard methods of analysis. The moisture is thus reported as bitumen and the resultant high figure misleads everybody concerned. In the days when all cold mixes were of the open type, the buyer was the most vitally interested party because methods which did not account for moisture, led him to believe he was getting more bitumen than was actually being delivered. Since the open mixes would hold without bleeding or pushing all the bitumen that practical handling would permit, the seller never objected to a high figure. Since the advent of the dense type cold mixes, the seller also is interested in seeing that moisture is not reported as bitumen for fear that his pavement may be classed as over-rich and his shipments rejected on that basis.

After trying out several methods requiring the use of a separate sample for moisture and a more or less laborious routine, it was found practicable to use a moisture trap just under the tip of the condenser in the N.Y.T.L. type extractor. That the moisture might be retained in the trap and the solvent overflow, it was necessary to use a solvent lighter than water, so benzol was chosen. The traps were made by cutting the conical lower ends from water and sediment tubes of the type shown in Figure I. These little conical vessels were held in a flame to dull the sharp edges and two pouring lips were formed opposite each other. The traps were placed in wire triangles on top of the extractor baskets. A photograph of the set-up is shown in Figure II.

Running samples of known moisture content revealed the fact that there is always a little moisture held back on the surface of the condenser. Under our conditions this was found to be quite con-

stant at five-tenths of a cubic centimeter. This correction is always added to the volume found in the trap. When the trap shows no moisture the condenser is examined. If it appears free of moisture,

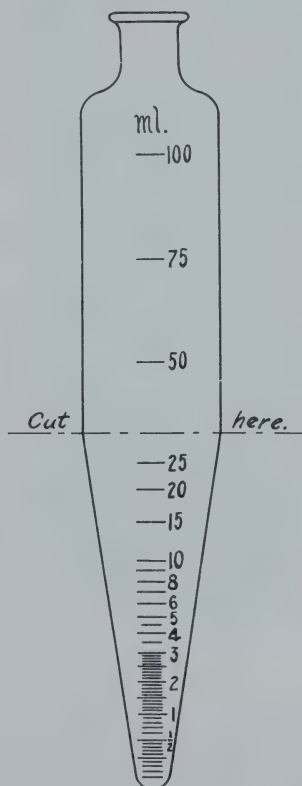


Fig. I

none is reported. If there is moisture on the condenser but none in the trap, we report "less than one-tenth per cent" (five hundred gram sample).

When using the N.Y.T.L. type of extractor all surface moisture, and a large proportion of any absorbed moisture, is

eliminated. When centrifugal extractors, such as the Rotarex, are used probably only the surface moisture would be carried away by the solvent. Mr. H. L. Howe asked that this fact be called to your attention. He suggests that aggregate from cold mixes should not be dried by means of heat, after centrifugal extraction, but simply air-dried so as not to alter the absorbed moisture content.

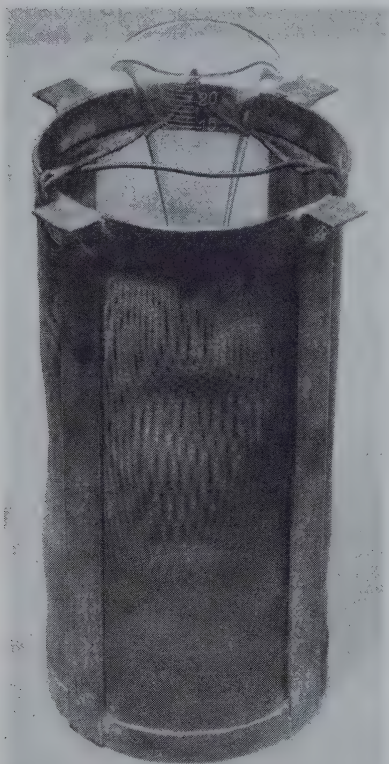


Fig. II

Care must be exercised in humid weather that the evaporation of the volatile solvent does not cause condensation and absorption of moisture by the aggregate, due to the marked lowering of temperature. Moisture carried out in the solvent can be recovered by means of A.S.T.M. Standard Method D 95-30, of which the trap used in our laboratory is a mere modification, the principle being the same. We used this method for a time and found it reliable but not so convenient as

the new one since it required a separate sample and set-up.

There is another point in technique which we find to be frequently overlooked in paving laboratories. After extraction, the figure for bitumen must be corrected for mineral matter which has passed through the filtering medium. This is usually accomplished by burning off the asphalt and weighing the residue. This figure is subtracted from the bitumen and added to the 200 mesh aggregate—the so-called “ash correction.” Because the last traces of the coke formed by the asphalt can only be removed by intense heating, any calcium or magnesium carbonates present in the mineral matter are usually reduced more or less to the corresponding oxides. Since calcium oxide has a molecular weight of 56, as compared to calcium carbonates at 100, and magnesium oxide has a molecular weight of 40, as compared to magnesium carbonate at 84, the resultant error is apt to be considerable.

The solution of this problem lies in treating the ash with a solution of ammonium carbonate and drying at 105° C. The oxides of calcium and magnesium are reconverted to carbonates and the excess reagent is dissipated as carbon dioxide, ammonia and water. It is usually necessary to repeat the treatment to make sure of total conversion.

Our laboratory is situated in the Grand Central Palace in the heart of New York City. The sooty smoke from our ash corrections became so objectionable to other denizens of the neighborhood that the Fire Department finally issued a “cease and desist” order. We ceased and desisted, turning to the centrifuge as a means of getting the mineral matter out of the bitumen solutions. The fluid from the extractor is centrifuged and the liquor poured off. Clean solvent is added to the sediment, which is stirred up and centrifuged again. It is then so clean that it is only necessary to dry and weigh. We have been checking this method by ashing our supernatant asphalt solutions to see how clean they have been stripped by the centrifuge. At 3000 R.P.M. there is often considerable sediment left in suspension but at 3500 the amount is very much smaller. So far we have not found any but negligible errors at speeds between 3500 and 4000 R.P.M.

The method would probably not be trustworthy when Trinidad or other asphalts, containing appreciable quantities of colloidal mineral matter, have been used, but where applicable it is fast, accurate and convenient.

Some years ago, at a meeting of this Association, Mr. Roehrich suggested the use of a little alcohol in the extractor solvent to hasten the elimination of the bitumen. The principle involved is the higher adhesion tension of the aggregate for the alcohol over bitumen and Mr. Roehrich's method is a very clever practical application of surface energy phenomena. Unfortunately, it will not work in those cases where the aggregate involved has a higher adhesion tension for bitumen than for alcohol, water, or similar hydroxyl compounds. Roughly stated, it works well with hydrophilic aggregates, poorly with hydrophobic aggregates. In our laboratories we endeavor always to select from local supplies the most hydrophobic aggregates available, other considerations permitting, because we believe this property protects the pavement against the disintegrating effects of moisture. In this respect, the filler is of

prime importance due to its high surface area. Fillers can be tested as to adhesion tensions for water and a fifty per cent solution of bitumen by a modification of the method given by Bartell and Hershberger (*Industrial and Engineering Chemistry*, Vol. 22, No. 12, December, 1930). It is necessary to run a comparison with the pure solvent used in the bitumen solution (we use benzol) in order to estimate the effect of the adhesion tension of the aggregate for the solvent in the results obtained. A study of surface energy reactions shows clearly that the liquid that wets a solid best is least absorbed by it. This will be a surprise to many, because it leads to the conclusion that, specific surfaces being comparable, the aggregate that will absorb the least asphalt will make the best pavement. The adhesion tension of the aggregate for the bitumen, other things being equal, determines the ultimate density of the pavement obtainable by compression, due to the fact that the surface energies involved are usually so far in excess of the forces of compression it is practical to apply on the street.

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(Paper presented at Tenth Annual Asphalt Paving Conference,
New Orleans, La., December 5-9, 1932. Technical Session of the
Association of Asphalt Paving Technologists.)

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Laboratory Compression of Asphalt Paving Mixtures, Double Plunger Method

By HENRY L. HOWE

President, The Association of Asphalt Paving Technologists

and

H. WALTER HUGHES

Supervisor of the Municipal Testing Laboratory, Rochester, N. Y.

At the Sixth Annual Asphalt Paving Conference held in 1927 under the auspices of The Asphalt Institute and The Association of Asphalt Paving Technologists, the speaker presented a paper entitled "Characteristics of Sheet Asphalt Paving Mixtures" which described in some detail the equipment and methods used in forming homogeneous cylindrical specimens of compressed asphalt paving mixtures upon which the various series of tests were applied.

The importance of being able to make sample cylinders under standard conditions, cheaply and easily, and at the same time to obtain uniform density throughout the specimen and in duplicate specimens of the same mixture within narrow limits of tolerance cannot be overestimated in research work to determine the characteristics of any of the various types of asphalt paving mixtures.

Apparatus for forming such cylindrical test specimens have varied from crude single plunger molds using a sledge hammer to compress the paving mixture, to complicated and relatively expensive electrically heated molds suitable only for use in a laboratory. The single plunger mold or the double plunger mold as described in the paper above referred to, furnish two simple, cheap, handy and reliable methods of making such cylindrical test specimens. In each method the plunger and mold is heated to 212° F. in boiling water just previous to use, and then placed under the head of a compression testing machine, or compressed by a hydraulic jack equipped with a pressure gauge. In this manner a choice of a method suitable for laboratory use and for use at the paving plant is furnished which will produce results with a good degree of accuracy.

A short series of tests was recently completed in our Municipal Testing Laboratory to determine the degree of uniformity of test cylinders made by the double plunger molds and the single plunger molds. A sheet asphalt medium traffic graded mixture with a dust ratio of 1 to 2 and a ten (10) per cent asphalt content was used in all cases, except the sample cores cut from actual pavements by use of the Riehle-Howe Asphalt Pavement Sampling Set. By dust ratio is meant the ratio by weight of the dust filler passing the 200-mesh sieve to the material between the 80 to 200 mesh sieve.

The materials were prepared separately for each cylinder, using three sand fractions—80 to 200, 40 to 80 and 10 to 40 sizes, a ground limestone filler all passing the 200-mesh sieve (retained 200-mesh material was screened out) and asphalt cement, all weighed cold and added to the hot mixing retort as described in the preceding paper referred to.

The materials were heated in the retort to the standard temperature of 325° F. and thoroughly mixed with a large spatula. The hot mixture was then transferred to the compression mold, all parts of which had been heated to 212° F. in boiling water and compressed in the manner described in detail in the previous paper. A "Compression Stain Print" was taken in each case to check the bitumen content and uniformity of mixing.

After the test cylinders were removed from the molds they were aged over night and their apparent specific gravity determined and voids figured in the usual manner.

Figure I shows graphically the results obtained on this mixture by using the double plunger, free or floating cylinder

method of compression, and those obtained by use of the single plunger method of compression, expressed as voids in the compressed mixture. In general, for these tests the Double Plunger Method, which permits an equalization of the friction of the mixture against the inside of the cylinder between the top and bottom plungers, gave the most consistent results showing variations from the average voids for all cylinders thus compressed of about one-half of one per cent (0.5%) plus and minus, whereas the single plunger method showed variations from the average of slightly less than three-quarters of one per cent (0.75%) plus or minus.

It is also interesting to note that the double plunger method resulted in reducing the voids in the compressed mixture about six-tenths of one per cent (0.62%) lower than those in the specimens compressed by the single plunger method.

The accuracy of both these methods could no doubt, be greatly improved by refinements in the technique, design of molds and particularly by the use of a smaller and more sensitive compression machine. A universal testing machine rated at 200,000 lbs. capacity was used in these tests for applying a load of only 10,590 lbs., or about five per cent (5.0%) of its rated capacity to obtain the standard load of 3,000 lbs. per square inch on the specimen.

The principal reason for developing the double plunger type of compression mold, however, was to obtain specimens for research purposes of uniform density on the top and bottom which was found to be impossible to do with the single plunger type of apparatus. Figure II shows graphically the difference in the density, expressed as voids in the mixture, between the top and bottom of test cylinders made by the two methods as above described. To obtain this data the cylinders were sawed in half and the voids determined separately on the top and bottom halves of each cylinder. It will

be noted that the difference in the top and bottom voids of the cylinders made by the double plunger method for any one cylinder does not vary in the series of tests more than a few tenths of one per cent either way, whereas for the cylinders made with the single plunger method, voids in the bottom are from one and one-quarter to one and one-half per cent (1.25% to 1.50%) higher than the voids in the top of the cylinder next to the plunger.

Figure III shows the results of another series of tests on the same mixture with similar results.

The question naturally arises as to which method more nearly represents the condition of pavement as represented in cores cut from the street.

Figure IV shows graphically the results expressed in voids in the compressed mixtures found by cutting in half sample cores taken from actual pavements. These results show that the voids in the pavement surface half averaged about one and three-quarters per cent (1.75%) higher than the bottom or lower half of the pavement wearing surface. This was probably due to the fact that the lower half of the pavement mixture was hotter than the top half when rolled during laying and, in consequence of this, compressed to a greater density. Whether or not this condition is general or even reverses in pavements under heavy traffic over a long period can only be determined by further studies of this character.

In conclusion it is suggested that research engineers who wish to study the characteristics of various pavement mixtures, hot or cold types, give consideration to the use of this double plunger method of compressing the sample specimens and at the same time check the mixtures for optimum bitumen content by use of the Compression Stain Print—which is many times more accurate than the old pat stain test.

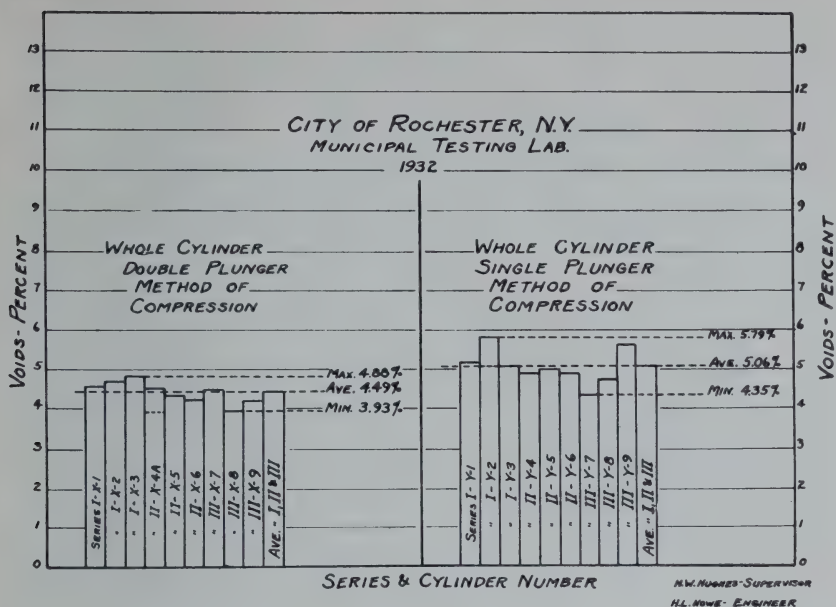


FIG. I.

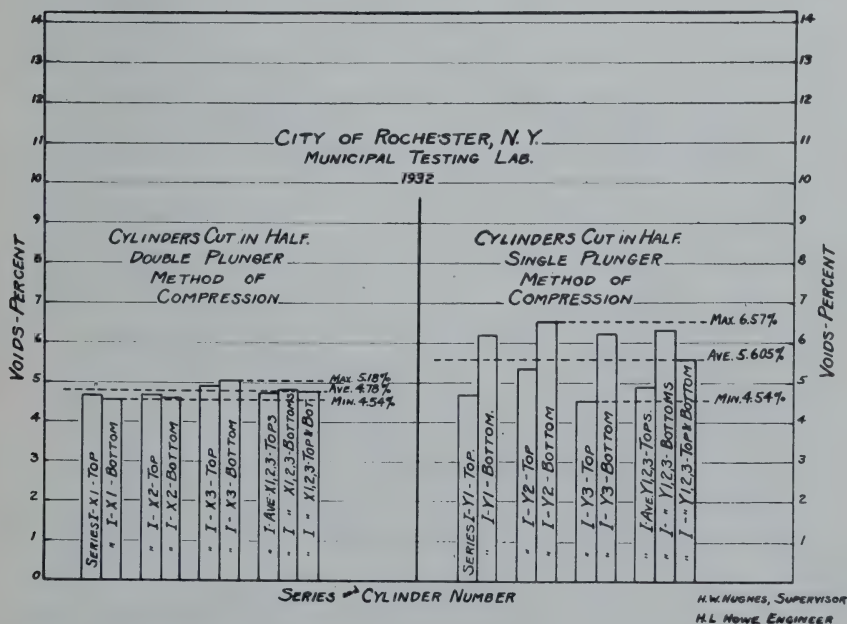


FIG. II.

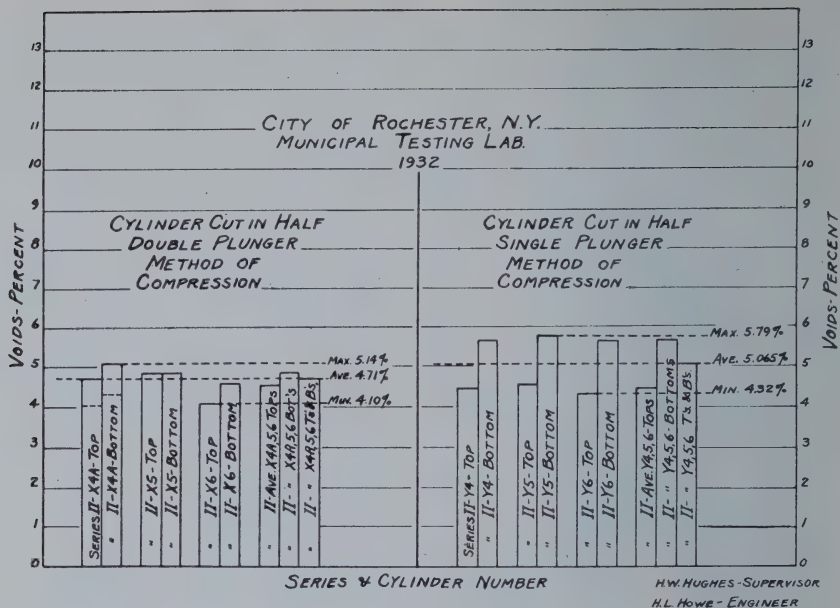


FIG. III.

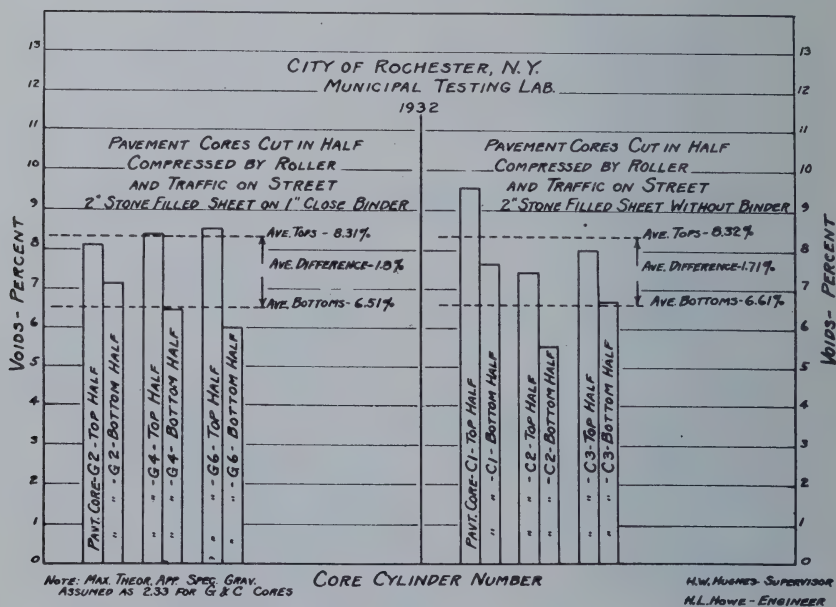


FIG. IV.

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Development of Asphaltic Materials in Canada

By R. M. SMITH

Deputy Minister, Ontario Department of Highways

Four years ago in this City of New Orleans, I presented a paper on "Asphalt and Its Uses in Ontario." Today I am expected to cover the Dominion—a vast area with temperatures from 50° below zero to 100° above, and with soils grading in consistency from the solid rock of British Columbia to the muskegs of Northern Ontario.

In Ontario our original idea was to develop, if possible, one asphaltic material that would meet all requirements, whether it was used for a mixed type of surface or surface treating. As a matter of fact, in our early construction we used an asphalt cement running penetration 71-80 and about 122° F. melting point, not only in the mix but for squeegee coat as well, and with excellent results. It is just possible the practice would still apply had we found it economical and feasible to apply this material with dispatch. Personally, I have always favored limiting the number of asphalts in use as far as possible. It provides for less confusion on the part of the purchaser and certainly reduces cost to the producer. As I have just stated, however, tremendous variations apply over the great areas of our country and consequently the producer has been obliged to develop a product that will meet all conditions. Ontario and Quebec generally have constructed so-called permanent road surfaces, while the other provinces have confined themselves almost entirely to the low cost surface.

Speaking for Ontario, we have built almost exclusively the well known black base, more commonly known by us as mixed macadam. This type, running into hundreds of miles, has proven very popular. The low cost, convenience of construction and comparatively non-skid surface have done much to recommend its consideration. The methods we have followed in constructing this type of pave-

ment have been brought to the attention of this conference before and it is not my thought to take time to review details. Sufficient to say that the aggregate consists of a crusher run stone with approximately 5 per cent asphalt content. The mixture is heated to 300° F. and applied to the road, properly spread and consolidated. Our contention, after six years of experimenting with this pavement, is that per ton of surface it is the cheapest type of bituminous surface that can be laid, given sufficient length of road so that the contractor can justify the installation of a mixing plant. The principal criticism that may be applied against the pavement is the fact that after years of wear it becomes slippery. It may also lose its shape, due to settlements in subgrade. This is easily understood when we recall that a 71-80 penetration asphalt running 122° F. melting point is used. In the early stages of development, we tried to coat the stone yet keep the asphalt content as low as possible. This prevented flushing to a considerable extent, but created a tendency to ravel. We accordingly increased the asphalt content concluding that an excess of asphalt was preferable to a lean mix. Our thought was that a surface treatment would eventually be developed that would take care of any slippery condition. We have tried asphaltic road oils, heavy, light and medium, also a variety of emulsions, and I am forced to confess that I hesitate to make a recommendation as to the proper type to use. However, the asphalt emulsion such as we obtain in Canada seems to give the best results. It also meets the popular demand for a surface that sets quickly and does not splash under traffic.

Keeping in mind that the only complaint we might receive so far as our mixed macadam surface is concerned is its slippery surface, we are this year ex-

perimenting with a new mix, called for purposes of identification, "The Rigid Asphalt Surface." While the methods we are following in the building of this pavement seem entirely contrary to what are accepted as good practice, we feel the experiment will be of interest to this convention.

Characteristics of Cement Concrete

The object is to determine to what extent we can duplicate some of the desirable characteristics of cement concrete and at the same time retain the useful characteristics inherent in bituminous paving mixtures.

Properties in cement concrete pavements considered worthy of duplication may be enumerated as follows:

1st—Its high structural or bridging strength at the critical temperature range when there is considerable movement in the subsoil. These disturbances, of course, are dependent not only on temperature but also on the natural condition of the subsoil in regard to texture, degree of compaction and composition. A well designed and strong concrete slab is capable of bridging over the small subsoil areas that become unstable due to excess of water, either water by direct filtration from the sides or by capillary action.

2nd—The non-skid characteristics of a cement concrete pavement: While we do not consider most concrete pavements entirely non-skid, especially those that have a smooth finish, we recognize that it is possible to make a rigid mixture entirely non-skid by roughening its surface.

3rd—Driving visibility by night. This is not so serious a matter but we cannot neglect the fact that a motorist is very favorably impressed with a surface the outlines of which he can easily distinguish at night.

1st—That it is a rigid solid and consequently has a far greater range of temperatures at which it will crack by expansion and contraction. The concrete remains rigid even at temperatures and at seasons of the year when bridging value or structural strength is not so important a factor on account of the subsoil having reached a state of repose,

which temperatures may be designated as those above 40° F.

2nd—Concrete being a rigid solid at the elevated temperatures, its life is directly dependent on its structural strength. Since it has no give or plasticity to speak of at times of the year when load impact is greatest, it stands more of a chance to break or crack than a layer that has a certain degree of resilience or plasticity.

3rd—It is extremely difficult to replace. Broken concrete is difficult to remove and even after repairing same by pouring in new cement concrete mixture, it is claimed it does not knead together with the surrounding old concrete and is an undesirable form of repair unless it covers a good sized area.

Rigid Type Bituminous Surface

It has been felt that a bituminous mixture could be designed that would have structural strength at low or the critical temperatures and be a partial plastic at summer temperatures.

Its rigidity could be made to such degree that, while its surface is rough or rather non-skid, this roughness of surface will remain that way without the tendency of flowing together. In other words, the consistency of the mixture is such that while it will have sufficient give under heavy impact and the high stresses set up by expansion, it will not flow to a degree where it will iron out to a smooth skiddy surface.

Bituminous mixtures irrespective of their rigidity can still be maintained by cutting out defective spots or areas and replacing with the same mixture. The points of contact between the patch and the old pavement can be preheated by means of a torch to ensure that the two weld together and that the patched area becomes part of the total slab.

It is also felt that even the visibility of our asphalt pavements can be improved considerably by reducing the fluidity of the mixture. It is very likely that a relatively rigid bituminous layer will assume a fairly light greyish color under traffic and will not smudge or darken up as an asphalt paving surface containing a 51-60 or even 31-40 penetration asphalt cement.



Showing center joint placed in rigid type asphaltic concrete



Close-up view of center joint and character of mix for rigid type asphaltic concrete

Our method of approach was therefore along two distinct lines:

(a) To tend toward dense mixtures. The mineral aggregate is so manipu-

lated as to have the highest degree of density.

(b) To use an asphalt cement of the following characteristics:

Penetration at	32° F.,	100 Grs. 5 Sec.	—	0
"	77° F.,	" "	—	5-10
"	100° F.,	" "	—	50 Maximum
"	140° F.,	" "	—	300 "

Softening Point (Ball and Ring)—Not essential but it is preferable that it should not be below 155° F.

Float Test At 140° F.—Over 3000 seconds, or to all intents and purposes still solid.

Viscosity at 300° F.—To be the same or lower than that of a 71-80 penetration paving asphalt we have been using in our black macadam work.

Solubility in Carbon Bisulphide—99.5%.

Insolubility in Paraffine Naphtha—14-19%.

In our experimental stretch we have tried to determine the following points:

1. Effect of increasing or decreasing of asphalt cement on compressive and tensil strengths at 32° F. and 77° F.

2. Effect of increasing and decreasing the quantity of dust on compressive and tensil strengths.

3. Effect of temperature both in preparing the mixture and in laying same.

4. Degree of compression or rather tamping necessary to make the whole mass thoroughly flow together.

5. Effect of varying grading from dust to coarse material passing 2" ring.

6. And last, the possibility of repairs by cutting out or removing the defective spots by preheating and refilling with new mixture.

In regard to the effect of increasing or decreasing asphalt cements we find, both by making experimental mixtures as well as specimens from the pavement, that decreasing the asphalt cement up to a certain point will yield higher strength values all along the line. In this regard it acts in very much the same way as all other bituminous mixtures, namely, that it is necessary to have just sufficient asphalt content to cover the surfaces and fill the voids. By filling the voids we mean that these are infinitesimal in size. The presence of actual voids is less harmful to the mixture than the presence of ex-

cess of asphalt content especially since the asphalt content used is hard and brittle.

In regard to 2—By varying the dust content from 5 to 20 per cent there has been a marked increase in strength of final mixture.

Temperature is a very important factor in that the higher the temperature the more fluid is the mass and it will consequently flow together more easily with the least amount of compaction. Mixtures have been prepared and laid at as high a temperature as 470° F. (the mineral aggregate only was preheated to 470° F.) and the effect was to increase the strength (provided mineral matter was used that was not affected by such extreme temperature). It is reasonable to expect that at high temperatures there would be a considerable hardening or rise in consistency of the asphalt. Volatility tests on the asphalt at 500° F., however, did not show that it in any way broke up. Extremely high temperatures, however, are impractical due to the mass becoming so fluid that it is impossible to maintain the proper crown or to hold the mixture to required thickness when laid on a slope. The greater portion of our work was with mixtures at 350° F.

It was found that if the mixture when placed on the road is of the proper consistency all it requires is tamping the same as cement concrete. Rolling is not essential and in fact would not be feasible



Finished surface asphaltic concrete (rigid type) prior to shoulders

even if we allowed the mixture to cool to a point where a tandem roller could be put on it, as the pushing action of the roller would tear the surface. What this type of mixture seems to require is thorough and rapid tamping. Since it is essential that the whole mass flow together, it is necessary to place the mixture in one layer of 6" or 7" average thickness so

that it retains its heat and has a certain degree of flow by its own weight, assisted further by tamping.

Variation of grading showed definitely that there are certain advantages in the mixture containing considerable fractions of the larger sized particles.

On the different sections we have used the following mineral aggregates:

- (A) Limestone Screenings — 900 lbs.
 To this was added Dust — 100 lbs.
 A. C. — 105 to 111 lbs.

- (B) Limestone Screenings — 350 lbs.
 Sand — 350 "
 Dust — 100 "
 A. C. — 75-82 lbs.

After above had been mixed for 45 seconds, 300 lbs. crushed stone ($\frac{3}{8}$ " to $1\frac{1}{4}$ ") were added and mixed for 10 seconds.

- (C) Limestone Screenings — 450 lbs.
 Fine Sand — 450 lbs. The mixture grading
 To this was added Dust — 100 lbs.
 A. C. — 100 to 105 lbs.

We had two bad spots. In one case the surface tore under improper tamping and we removed a section 10' across, 4" wide and approximately 3" deep. This defective spot, after it had been properly trimmed off was preheated and new material tamped into it, using a hot tamper.

The repaired section after it had set, and incidentally we might mention it was also covered by snow and ice, was tested by two men swinging 10 lb. sledge hammers. The hammer impact showed that the whole mass was thoroughly welded together. On another section the tempera-

ture of the mixture was so high that the surface became extremely rough and uneven. This also was removed by the same method and repaired with the same satisfactory results.

We might also mention that the application of coarse sand over the tamped mixture while the surface is still hot and rich looking makes it possible to get a thorough non-skid surface. This non-skid appearance is due not to the sand but rather to that subsequent compaction or tamping on top of the sand which slightly roughens the surface to give it the non-skid appearance.

NOTE: The average compressive strength of the various mixtures applied on our experimental stretch would be as follows:
at 32° F. — 4490 pounds
at 65° F. — 2300 pounds

Failure at 32° F. was instantaneous and in a manner that indicated that the mass was a rigid solid.

Failure at 65° F. had a time element and distortion was such as to indicate that at that temperature it has a certain degree of plasticity.

Low-Cost Asphalt Types

In Canada, as in the United States, we have a wide variety in our highway development problems, geographically speaking. Our four Western Provinces of Manitoba, Saskatchewan, Alberta and British Columbia having a widely scattered, sparse population, are principally agricultural, with consequent huge highway mileages and very limited funds for highway purposes. In order to provide their citizens with some form of reasonable, all-weather transportation facilities, these provinces have attempted to extend as rapidly as possible plain gravel surfaces on their graded clay subgrades, but unfortunately these untreated gravel surfaces are high in first cost, because much of the gravel involves train haul and, secondly, are expensive to maintain due to the loss of gravel in the clay during wet spells, particularly in those areas where traffic is comparatively heavier.

Highway engineers in those four provinces—having observed and studied low cost asphalt types developed in such states as Wisconsin, Minnesota, Utah, Montana and Washington—have been

experimenting along similar lines and have finished some very creditable mileages of low cost asphalt surfaces. In general, development has been along the lines of double blotter treatments on clay subgrades and both plant and surface mix types of gravel and asphalt laid to a compacted thickness of from 1½" to 3"

In "Blotter" treatments the procedure usually is to first blade the clay subgrade to remove as much loose clay as possible and to establish proper contour on the subgrade. This is followed by an application of half gallon of a non-volatile asphalt primer of 30 to 60 Furol viscosity at 122° F. After this has soaked into the road for several hours gravel, all of which passes a 1" screen, and which has been previously windrowed on the sides of the road at the rate of about 500 cubic yards per mile of 20-foot road, is then bladed into the primer and uniformly distributed over the whole 20 feet. A second application of half gallon of a heavier non-volatile material of from 100 to 175 Furol viscosity at 122° F. is then made on the spread gravel, and the whole is then mixed with blade graders until uniformity is obtained. The resulting mixture is carefully spread over the whole 20 feet and allowed to consolidate under traffic.

In mix-in-place gravel construction additional mineral aggregate is added as required, to give sufficient depth. Liquid asphalts are then sprayed on in two or more applications to the required amount and mixed with blade graders, uniformly spread and allowed to compact under traffic. While formerly non-volatile liquid asphalts—ranging from 300 to 800 Furol viscosity—were used in this type of work, our Western Provinces are rapidly standardizing on a bitumen made by cutting back a relatively soft asphalt cement with a volatile solvent to a viscosity of from 200 to 300 Furol viscosity at 122° F. The use of such a material permits easier mixing under a wider variety of atmospheric temperatures, more uniformity in the mixes and greater resistance to water infiltration and disintegration in the finally compacted surfaces.

Plant mix methods, as applied to low cost gravel surfaces in Western Canada, do not depart very radically from standard practice, except that the premixed asphalt and gravel frequently were shipped

by rail considerable distances for unloading and spreading at destination. In Western Canada, we have been using a straight run heavy asphaltic material of from 1000 to 1600 Furol viscosity at 122° F. The use of such heavy materials, although of advantage possibly in the finally consolidated road, approaches hot mix construction methods and has a tendency to lose sight of the fundamentals of low cost road development. Surfaces laid with such stiff materials are not easily scarified or broken up, should same become necessary, even in warm summer temperatures. When one considers the large mileage of successful mix-in-place roads in the North American Continent with bitumens of relatively low viscosity, it would seem that, even in plant mix work where the aggregate and asphalt are warmed, an asphalt of from 700 to 1000 viscosity at 122° F. should be adequate, and in conformity with the theories of low cost practice.

In Ontario, in the last few years, several of our counties have been exploring the possibilities of low cost asphalt types and considerable progress has been made. Experimental work has followed along the lines of standard practice: viz. (1) single, double and triple surface treatments of compacted gravel and macadam roads, using a priming asphalt of low viscosity and heavier bitumens for the succeeding applications with mineral coverings, careful dragging and rolling; (2) mix-in-place graded aggregate types employing a soft asphalt cement of about 80° F. softening point, cut back with a volatile solvent to a viscosity of 150-200 Furol at 122° F.; (3) pre-mix or plant-mix graded aggregate with an asphalt of 800 to 1000 viscosity Furol at 122°

F., and (4) mix-in-place macadam aggregate types, using asphalt emulsions and a paving cement cut back to 200-250 Furol viscosity at 122° F. Methods employed in all these types conform to the usual practice, so that details are unnecessary.

Economic Value

In attempting to evaluate the economics of low cost asphalt surfaces, we feel in Canada that to be economic, these types must be what they are called; viz., low cost. Resorting to unnecessarily expensive and carefully graded aggregate and to complicated, costly equipment and to unnecessarily stringent specifications for bituminous materials, naturally defeats the fundamental idea behind low cost highways which after all is to rapidly expand at minimum expense all-weather, dustless transportation facilities to the greatest number of people residing on roads with only fairly heavy traffic, and who should have continuous access to markets, schools, etc. If each type of low cost improvement is carefully selected and economically done, with the idea ever in the highway engineer's mind that what he has done has maximum salvage value and can be added to from time to time as traffic demands and finances permit, then only can these low cost types prove really economic. During these difficult times, when highway funds are not so readily obtainable and where the demand for better and greatly extended highway facilities has not abated, the taxpayer is going to be more critical in his attitude towards highway engineering, and take more than the usual casual interest in highway administration.

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Relative Viscosities of Liquid Asphaltic Road Materials at Various Test Temperatures

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A review of the 1931 state specifications, submitted to the Bureau of Public Roads in connection with the cooperative work on the simplification of tests for liquid asphaltic materials, showed that there was considerable difference of opinion as to the temperatures at which viscosity determinations should be made. The following tabulation gives the number of specifications and the temperature at which the viscosity determinations were designated to be made in these specifications:

Designated Temperature	Number of Specifications
77° F.	39
104° F.	12
122° F.	87
140° F.	16
194° F.	2
210° F.	1
212° F.	7
302° F.	1

The consistency requirements of the hot application materials were controlled not only by viscosities at the higher temperatures (194° F., 212° F. and 302° F.), but also by the float test at 90° or 122° F. and, in some cases, by both a viscosity and a float test.

At the regional meetings which considered the various tests, the Furol viscosity was adopted and the temperatures generally recommended for viscosity determinations were 77° F., 122° F. and 210° F. There were, however, some who favored the float test at 122° F. as a single measure of consistency instead of the Furol viscosity at 210° F.

There was a fairly general agreement on the choice of 122° F. as a test temperature with the following exceptions:

(a) Two States voted for the use of

104° F. as a test temperature instead of 122° F.

(b) Eight States in Region 3, although they did not vote for Furol viscosity determinations at temperatures other than 77° F., 122° F. and 210° F., stated that they believed some temperature between 122° F. and 210° F. would be desirable.

(c) Seven states voted for the use of 140° F. as a control temperature for viscosities in addition to the other three generally accepted.

The 1932 state specifications also show the wide difference of opinion as to the proper temperature to be used for viscosity determinations. In addition to the temperatures already listed, there have been specified during 1932 two others, namely 180° F. and 200° F. It is therefore apparent that there is considerable doubt as to the sufficiency of 122° F. as the single intermediate temperature; and there is a question as to whether a high temperature viscosity for the control of hot application materials could not be discarded advantageously for some other consistency test.

The maximum viscosity limits in terms of the Saybolt Furol instrument under the 1931 specification for each test temperature are given in the following table:

Temperature ° F.	Maximum Time Seconds
77	480
104	436
122	1200
140	260
194	440
210	180
212	320

One of the important advantages of the Furol instrument over the Engler is the shorter time required in making a viscosity determination. This time advantage should be retained by the selection of suitable test temperatures such as will insure accurate determinations in a reasonable time. It can be seen from the preceding table that the maximum time for the test at 122° F. is much greater than for the other temperatures. The maximum time of 1200 seconds or 20 minutes shows the extreme to which we lose this time advantage of the Furol instrument.

While there are only twelve 1931 specifications having maximum viscosity limits of over 500 seconds Furol at 122° F., there is nevertheless a trend towards the use of more viscous materials. These materials, considerably thinner than hot application materials, are used extensively in retread and oiled road mix construction. The viscosities of these asphaltic products are very high when run at 122° F. and, in order to determine the suitability of the next higher temperature for the control of these materials, adopted at the regional meetings, viscosities at 210° F. were run on a selected number of road oils and kerosene cut-back asphalts. Float tests at 122° F. were also made on the same samples.

The relationships existing between the Furol viscosity at 122° F. and the Furol viscosity at 210° F. and the float test at 122° F. for the liquid asphaltic road materials of the slow curing type are given in Table I and are plotted in Figure 1. The materials tested were from many different fields and were, no doubt, produced by quite different methods of processing. Consequently, no satisfactory curve could be drawn in Figure 1 to show the relationship for the different consistency values, although a definite trend is indicated.

The same relationships for kerosene cut-backs are given in Table 2 and Figure 3. Although the sources of these cut-backs are all different, a fairly satisfactory curve can be drawn to show the relationship between viscosities at 122° F. and viscosities at 210° F. and between viscosities at 122° F. and float tests at 122° F. These relationships may be expressed approximately as follows:

$$C = .03 B + 18$$

$$D = .02 B + 10$$

Where B = Furol viscosity at 122° F.

C = Furol viscosity at 210° F. and

D = Float test at 122° F.

The narrow range between the maximum and minimum values for viscosities at 210° F. and for float tests at 122° F. on materials which had a wide range of viscosity at 122° F. indicates that these tests could not be expected to furnish sharp differentiation between various consistencies.

In order, therefore, to determine a suitable viscosity temperature for these materials, five selected kerosene cut-backs, having appreciable differences in viscosity at 122° F., were tested for viscosity at the following temperatures: 122° F., 140° F., 158° F., 176° F., 194° F. and 210° F. The results of these determinations are given in Table 3 and are shown graphically in Figure 5.

It can be seen that an 18° increase in temperature from 122° F. to 140° F. decreases the time of the Furol viscosity more than one-half even for the least viscous material. Therefore, since the 140° F. temperature has been used by some of the States and since this temperature is being considered for use by other States, it was thought desirable to investigate the viscosity values at this temperature on a considerable number of liquid asphaltic road materials of the slow, medium and rapid curing types.

The data for viscosities at 140° F. for materials of the slow curing type are given in Table 1, and for materials of the medium curing type in Table 2. While naphtha cut-backs (materials of the rapid curing type) were not used in the preliminary work, a number of samples of various consistencies from different producers have been tested at 140° F. as well as 122° F. The data on these naphtha cut-backs are given in Table 4. The data for liquid asphaltic road materials of the slow curing type are plotted in Figure 2, for kerosene cut-backs in Figure 4 and for naphtha cut-backs in Figure 6.

In drawing the curve for materials of the slow curing type in Figure 2, it was

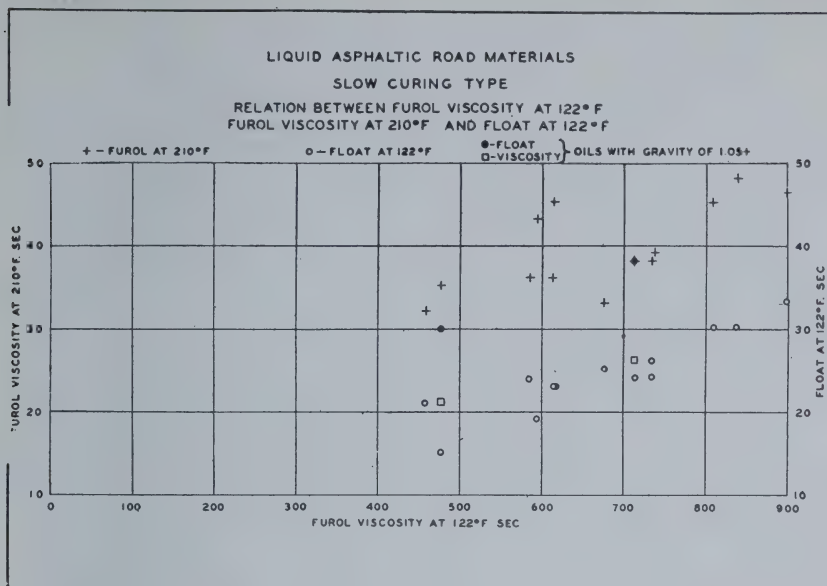


Fig. 1

found that some of the points differed greatly from the trend of results obtained and, in checking the test reports on these samples, it was found that these particu-

lar materials all had a high specific gravity greater than 1.05, while the gravities of the other materials were all less than 1.003. Two curves were therefore drawn

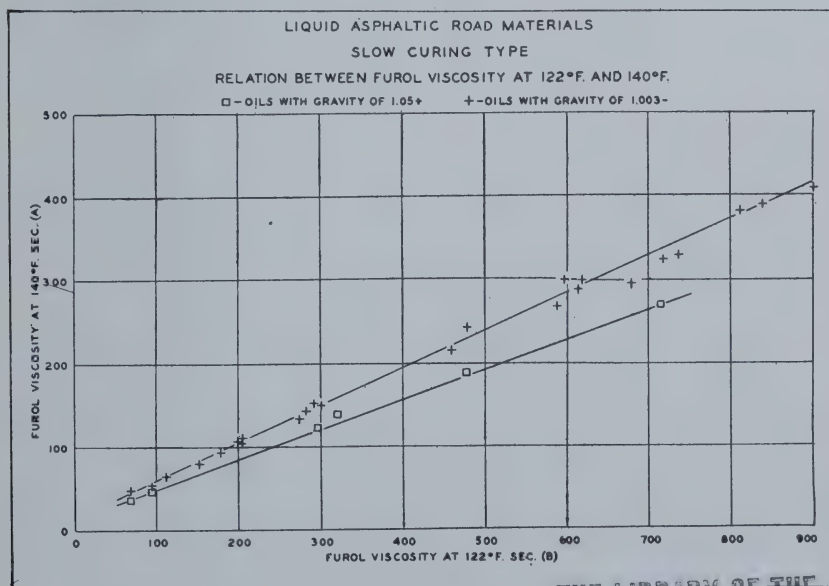


Fig. 2

and the relationship may be expressed approximately as follows:

$$A = .45 B + 15 \text{ for the low gravity group}$$

$$A = .36 B + 15 \text{ for the high gravity group}$$

Where A = Furol viscosity at 140° F. and

$$B = \text{Furol viscosity at } 122^{\circ} \text{ F.}$$

The relationship for the kerosene cut-backs, as shown in Figure 4, may be expressed approximately as follows:

$$A = .4 B + 40$$

Where A = Furol viscosity at 140° F. and

$$B = \text{Furol viscosity at } 122^{\circ} \text{ F.}$$

The relationship for naphtha cut-backs, as shown in Figure 6, is approximately as follows:

$$A = .4 B + 60$$

Where A = Furol viscosity at 140° F. and

$$B = \text{Furol viscosity at } 122^{\circ} \text{ F.}$$

It is believed that a continuous flow through the aperture of the viscosimeter is necessary for obtaining an accurate viscosity determination. To secure this, the control temperature should be so adjusted as to avoid the dripping which occurs when high viscosities are run. In Table 1 there is dripping on all viscosities over 478 at 122° F. and when these same samples are run at 140° F. no dripping occurs.

In Table 2 the kerosene cut-backs, having in the majority of cases much higher viscosities than the road oils listed in Table 1, drip at both temperatures, 122 and 140° F. although the difference between time to drip and the viscosity value is much smaller at 140° F. than at 122° F. The time to drip was not recorded on the naphtha cut-back determinations, but it is probable that dripping did occur on the more viscous materials at both temperatures.

It is evident from the study of the results of other operators on viscosity determinations at 122° F. on samples tested by the Bureau that the differences in test values in cases of the heavier materials (Tables 1, 2 and 4) are quite large, and it is reasonable to suppose that, if accurate temperature control is

secured, the differences in viscosity values of various operators should be materially reduced by the use of 140° F. as a temperature control because the total time during which the viscosity determination is being run is greatly shortened and uncontrollable factors which affect the accuracy of the determinations have considerably less time to influence the flow of oil into the receiver. Since the time of running the test at 140° F. is greatly reduced and the dripping is less, check tests by different operators should be in closer agreement.

Therefore, since 140° F. also represents the approximate maximum temperature reached in the upper portion of the road under summer temperature conditions, it is thought that it is a desirable intermediate temperature for the control of the more viscous products which have high Furol viscosities at 122° F.

Recently there have been used very viscous liquid asphaltic road materials of the medium and rapid curing types in the construction of road mixes, prepared in a portable road mixing plant, immediately laid down and compacted. These materials have exceedingly high viscosities at 140° F. If naphtha has been used as the cutting medium in these products, it is not thought advisable to use a temperature higher than 140° F. for the viscosity determination because of the possible loss of volatile matter and subsequent stiffening of the material during the test. However, if kerosene is the solvent used in these cut-backs, a viscosity determination at some higher temperature than 140° F. is not only possible but is also desirable because of the shorter time involved in making the test. Several States using material of this grade have designated 180° F. as the control temperature for the viscosity determination.

The Furol viscosities of extremely viscous medium curing materials at 140° F., 180° F. and 210° F., as well as float tests at 122° F., are given in Table 5. Curves showing the relationship existing are plotted in Figure 7. It is readily apparent that material having such a high viscosity at 140° F. can be satisfactorily controlled by a Furol viscosity at 180° F. and that the use of 210° F. as a viscosity temperature control for this type of material is not necessary.

The consistency requirements for ma-

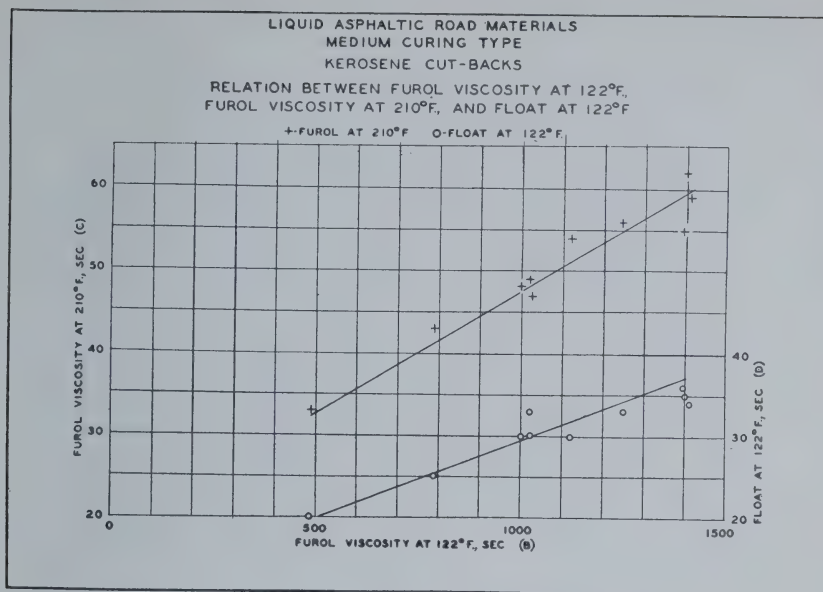


Fig. 3

materials to be used in hot surface treatments are generally specified by viscosities at one of the higher temperatures or by a float test at 90° F. or 122° F. In many

cases the consistency is controlled by both a viscosity at a high temperature and a float test.

The method of application of the

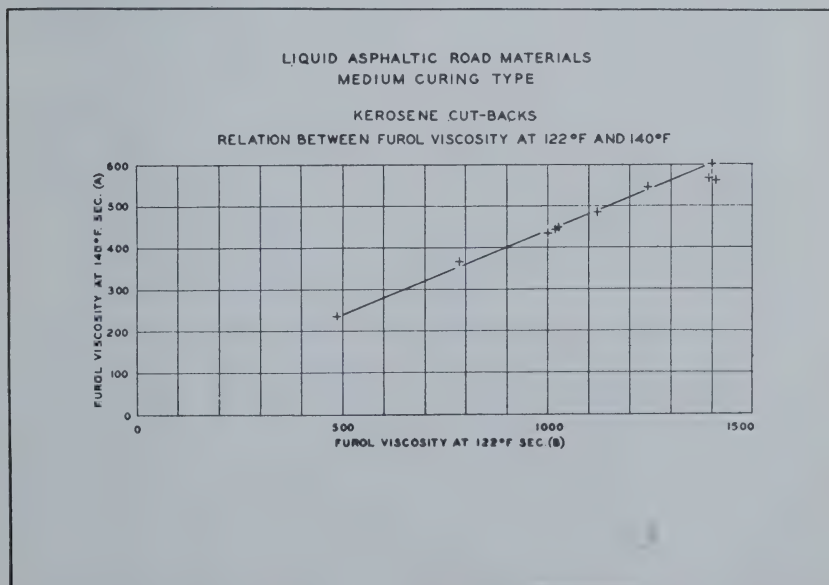


Fig 4

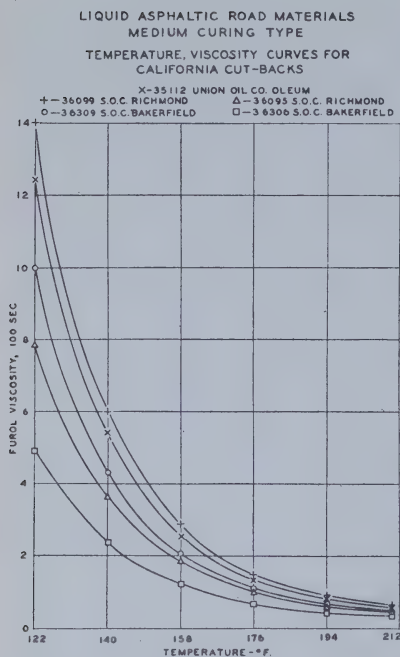


Fig 5

grade of bituminous material to the road surface is similar to the method of handling bituminous materials used in penetration macadam. In specifications for the latter materials no viscosity requirement is made. Therefore, it is believed that the viscosity requirement at the high temperature on hot surface treatment material can be readily discarded from the specifications and that some test measuring the consistency of the material at a lower temperature can be substituted.

With this idea in mind, a large number of liquid asphaltic road materials of this type were tested for Furoil viscosities at 210° F., for float at 122° F., 140° F., 150° F. and 176° F., and penetrations at 77° F. under variable load and time were made. The results of this series of tests are given in Table 6 and the relationship between Furoil at 210° F. and float test at 122° F. and 176° F. are shown in Figure 8. The effects of change in temperatures on the float test values for a selected number of samples are shown in Figure 9.

It is evident that the float test at 122° F. has no direct relationship to Furoil viscosity at 210° F. for the materials

tested, although data not included in this report indicate that there is a definite relation between floats at 122° F. and viscosities at 210° F. if the materials have been produced from the same base materials and by the same process. If the floats are made at a higher temperature, the test becomes more nearly a measure of consistency for all types of material as is shown in Figure 8, as a fairly satisfactory curve can be drawn to show the relationship between Furoil viscosity at 210° F. and float test at 176° F.

The one outstanding feature developed by the various consistency tests is that although these products are often considered as fluid asphaltic materials, 14 of the group tested gave penetrations at 77° F., 100 grams, 5 seconds, of 264 to as low as 121, and that only ten may be considered as liquid bituminous materials as such materials are defined by the American Society for Testing Materials, namely, those materials having a penetration at 77° F. under a load of 50 grams applied for 1 second, of more than 350. The viscosity determination at high temperatures for this class of materials is unnecessary. A float test could be used, but the designation of a soft semisolid asphalt controlled by a penetration test at 77° F. under a load of either 50 or 100 grams would seem to offer the better means for laboratory control and insure the elimination of extremely high viscosity temperatures.

This investigation indicates that

1. There is need for a number of temperatures to adequately cover the wide range in consistency of liquid asphaltic road materials.

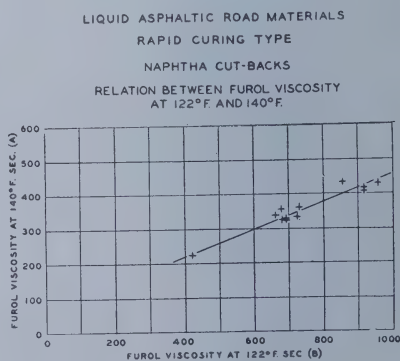


Fig. 6

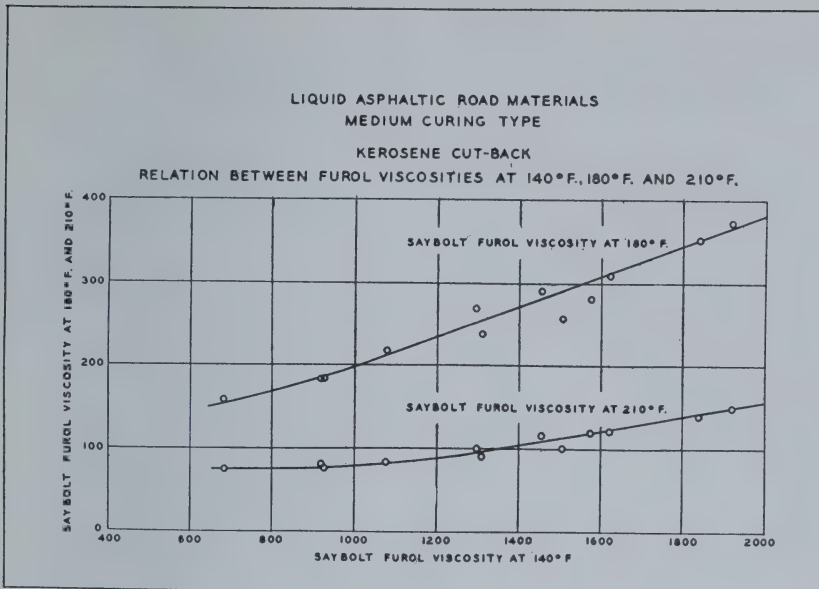


Fig. 7

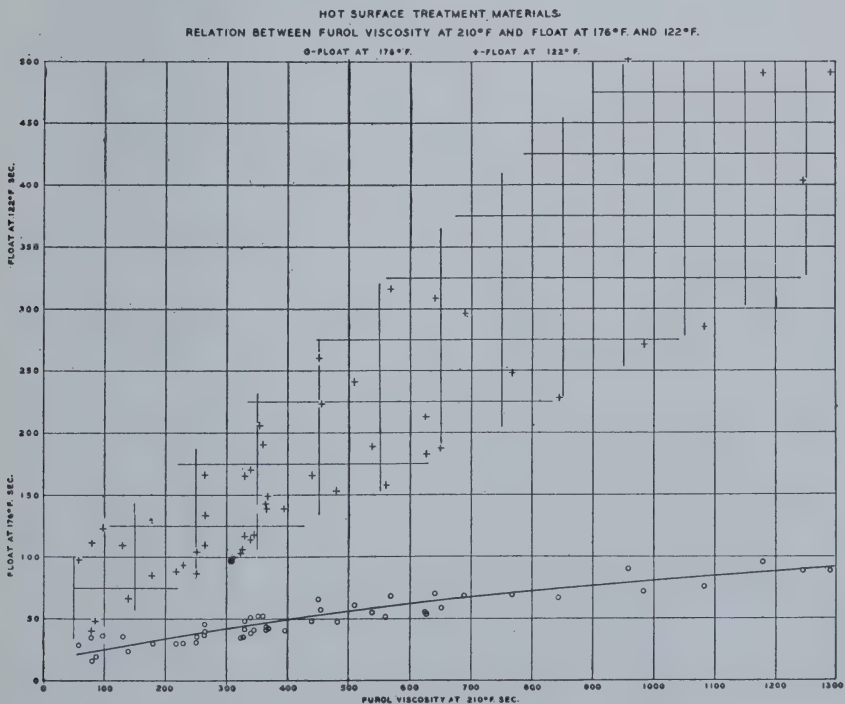


Fig. 8

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2. The use of 140° F. and 180° F. should prove satisfactory as control temperatures in Furol viscosity determination for the more viscous liquid asphaltic road materials.

3. The temperature designated for control should be, where practicable, that which will give a Furol viscosity of less than 500 seconds. However, the more viscous materials of the rapid curing type should not be tested for viscosity at a temperature higher than 140° F.

4. Many so-called liquid asphaltic road materials, which are used in hot surface treatment work, and which are designated as hot oils, 90 and 95 per cent road oils, etc., are in fact semi-solid asphaltic materials. These grades of material probably can be controlled best for consistency by either a float test at a low temperature or by a penetration test at 77° F. under a load of 50 or 100 grams.

5. The use of a temperature of approximately 210° F. can be omitted readily from specifications for liquid asphaltic road materials.

TEMPERATURE FLOAT TEST CURVES
HOT SURFACE TREATMENT MATERIAL

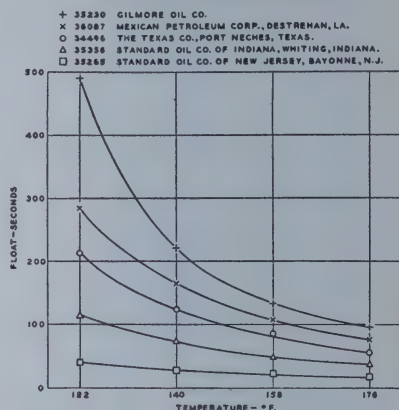


Fig. 9

TABLE 1

Furol Viscosities of Liquid Asphaltic Road Materials of the Slow Curing Type at 122°F., 140°F. and 210°F., and Float Tests at 122°F.

B. P. R. No.	PRODUCER	Spec. Grav.	122°F.		140°F. Viscosity	210°F. Viscosity	Float Test at 122°F.	Results of other Operators at 122°F.	
			Viscosity	Time to Drip				Max. Visc.	Min. Visc.
			Sec.	Sec.	Sec.	Sec.	Sec.	Sec.	Sec.
34453	Utah Ref. Co.	1.079	68		36				
35364	Shell, Wood River	0.942	68		47			68	64
34263	White Eagle	1.066	94		48			105	90
35100	Shell, E. Chicago	1.001	94		53			91	89
35077	Shell, Martinez	0.951	111		63			111	111
36303	S. O. Calif., Bakersfield	0.967	151		80			150*	150
36106	S. O. Calif., Richmond	0.952	178		94			174*	174
35367	Shell, Wood River	0.955	199		106			194	185
35226	Gilmore, Los Angeles	0.967	201		104			198	198
35103	Shell, E. Chicago	1.003	205		110			196	192
36310	S. O. Calif., Bakersfield	0.972	274		134			280*	280
35080	Shell, Martinez	0.963	281		142			300	261
35157	White Eagle	0.976	294		152			308	245
34454	Utah Ref. Co.	1.101	297		123				
35225	Gilmore, Los Angeles	0.972	300		148			311	255
36089	S. O. Calif., Richmond	0.960	300		149			300	287
34322	Lincoln Oil Co.	1.082	320		137			345	292
36091	S. O. Calif., Richmond	0.966	458		220	32	21	500	444
34323	Lincoln Oil Co.	1.088	478		188	21	30	496	444
36360	Berry	0.981	478	405	243	35	15		
34467	Union, Oleum		586	440	268	36	24	580	530
36946	MacMillan	0.979	596	480	301	43	19	566	564
35081	Shell, Martinez	0.972	613	x	288	36	23	630	616
35221	Texas, Port Neches	0.975	616	540	300	45	23	627	567
36300	S. O. Calif., Bakersfield	0.981	677	400	295	33	25	720	680
35155	S. O. Indiana, Wood River	1.087	713	560	271	26	38	707	660
36211	S. O. Calif., El Segundo		716	480	325	38	24	798*	798
35228	Gilmore, Los Angeles	0.979	735	x	333	38	26	706*	706
36214	S. O. Calif., El Segundo		737	450	333	39	24	760	730
35183	S. O. Indiana, Greybull	0.982	808	540	384	45	30	831	790
34279	White Eagle		838	600	392	48	30	852	805
36426	Texas, Cody	1.003	898	600	410	46	33	908	850

* Only one determination.
x Not recorded.

TABLE 2

Furol Viscosities of Kerosene Cut-Backs at 122°F., 140°F. and 210°F.
and Float Test at 122°F.

B. P. R. No.	PRODUCER	Location	122°F.		140°F.		Vis- cosity 210°F.	Float Test 122°F.	Results of other Operators 122°F.	
			Vis- cosity	Time to Drip	Vis- cosity	Time to Drip			Max. Visc.	Min. Visc.
36306	S. O. Calif.....	Bakersfield.....	Sec. 488		Sec. 238		Sec. 33	Sec. 20	Sec. 550	Sec. 530
36095	S. O. Calif.....	Richmond.....	787	540	366		43	25	820	750
36309	S. O. Calif.....	Bakersfield.....	999	550	432	410	48	30	1080	991
35114	Union Oil Co.....	Oleum.....	1020	500	445	420	49	33	964	806
35113	Union Oil Co.....	Oleum.....	1023	600	449	420	47	30	1105	950
36097	S. O. Calif.....	Richmond.....	1120	600	486	425	54	30	1175	1100
35112	Union Oil Co.....	Oleum.....	1247	600	542	435	56	33	1238	1015
36524	Associated.....	Calif.....	1393	700	567	450	55	36	1450	1249
36099	S. O. Calif.....	Richmond.....	1400	600	600	435	62	35		
36094	S. O. Calif.....	Richmond.....	1411	630	559	450	59	34	1542	1400

TABLE 3

Furol Viscosities of Kerosene Cut-Backs at Various Temperatures

B. P. R. No.	PRODUCERS	Viscosity at					
		122°F.	140°F.	158°F.	176°F.	194°F.	210°F.
		Sec.	Sec.	Sec.	Sec.	Sec.	Sec.
36306	S. O. Co. Calif., Bakersfield.....	488	238	121	69	44	33
36095	S. O. Co. Calif., Richmond.....	787	366	187	101	62	43
36309	S. O. Co. Calif., Bakersfield.....	999	432	207	111	67	48
35112	Union Oil Co., Oleum.....	1247	542	258	136	81	56
36099	S. O. Co. Calif.....	1400	600	290	151	88	62

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TABLE 4

Furol Viscosities of Naphtha Cut-Backs at 122°F. and 140°F.

B. P. R. No.	PRODUCER	Viscosity at		Results of other Operators at 122°F.	
		122°F.	140°F.	Min.	Max.
		Sec.	Sec.	Sec.	Sec.
35486	Shell, Norco.....	420	226	426	455
34286	Barber.....	662	338	651	725
34314	S. O. New Jersey, Baltimore..	680	358	729	804
35208	S. O. Louisiana.....	681	325	685	702
34377	White Eagle.....	688	322	557	792
35347	S. O. Indiana, Whiting.....	689	327	676	809
35478	Texas, Port Neches.....	725	334	577	844
36059	Shell, Norco.....	730	360	604	875
36058	Shell, Norco.....	854	432	756	1060
35207	S. O. Louisiana.....	919	418	895	914
34317	S. O. New Jersey, Baltimore..	919	404	900	936
35474	Texas, Port Neches.....	960	430	844	1060

TABLE 5

Furol Viscosities and Floats on Kerosene Cut-Backs at Various Temperatures

B. P. R. Number		PRODUCER	Viscosity at			Float Test at 122°F.
Base	Flux		140°F.	180°F.	210°F.	
36769	36608	Mex. Pet. (Balt.).....	1920	372	148	75.5
			1840	352	139	70.0
			1455	290	116	58.0
			682	159	75	40.0
34326	Kerosene No number	White Eagle (Casper).....	1622	309	122	78.0
			1576	281	121	
			1298	270	100	68.5
			920	183	81	55.0
35120	35122	Union Oil Co. of Calif.....	1506	256	100	67.0
			1310	240	90	64.5
			1077	218	84	59.0
			925	183	76	50.5

TABLE 6

Liquid Asphaltic Road Materials—Slow Curing Type

Furol Viscosities at 210 °F., Float Tests at 122 °F., 140 °F., 158 °F.
and Penetrations at 77 °F.

B.P.R. No.	PRODUCERS	Furol 210 °F.	Float Test at				Penetrations at 77 °F.			
							50 grams		100 grams	
			122 °F.	140 °F.	158 °F.	176 °F.	5 Sec.	1 Sec.	5 Sec.	1 Sec.
		Sec.	Sec.	Sec.	Sec.	Sec.				
35145	Standard Oil Co. Ind., Wood River	60	97	55	40	28		249		
35265	Standard Oil Co. N. J., Bayonne	83	39	27	21	16		T. S.		
35356	Standard Oil Co. Ind., Whiting	83	111	74	48	35		180		
34254	The Texas Co., Bayonne	89	48	32	23	18		T. S.		
35196	Standard Oil Co. N. J., Parkersburg	100	123	77	51	36	310 +	189		
35353	Standard Oil Co. Ind., Whiting	133	108	70	48	35		191		
36044	Jas. B. Berry	143	66	42	32	24		T. S.		
35266	Standard Oil Co. N. J., Bayonne	181	85	56	36	30		T. S.		
35267	Standard Oil Co. N. J., Bayonne	220	88	58	40	30		T. S.		
34248	The Texas Co., Bayonne	232	93	60	41	30	300 +	T. S.		
36343	Shell Oil Co., Norco	253	87	64	42	32		T. S.		
35048	Standard Oil Co. N. J., Baltimore	254	104	74	50	35		242		
36307	Standard Oil Co. Calif., Bakersfield	266	166	107	68	46	294 +	105		
36863	Mex. Pet. Corp. Baltimore, Md.	267	109	74	50	37		T. S.		
36216	Standard Oil Co. Calif., El Segundo	267	133	83	57	39	283 +	175		
34497	The Texas Co., Port Neches	326	103	71	50	35		T. S.		
36187	Atlantic Ref. Co., Brunswick, Ga.	328	105	76	50	35		266		
36085	Mex. Pet. Corp., Destrahan, La.	331	117	79	57	41		249		
36093	Standard Oil Co., Richmond	333	165	104	69	48	285 +	118		
36759	The Texas Co., Bayonne	342	115	75	54	38		T. S.		
35083	Shell Oil Co., Martinez, Calif.	342	171	111	75	51	277	111	303 +	200
35335	Standard Oil Co. N. Y., Riverside	347	118	80	56	40		268		
36311	Standard Oil Co. Calif., Bakersfield	355	206	119	82	52	193	83	232	
35115	Union Oil Co., Oleum	362	191	114	76	52	242	115	291 +	199
37323	The Texas Co., Bayonne	366	142	92	63	42	255 +	149		
35348	Standard Oil Co. Ind., Whiting	367	139	89	65	43	315 +	263		
35049	Standard Oil Co. N. J., Baltimore	369	149	97	65	42	281 +	172		
35013	Standard Oil Co. Ohio	398	139	92	61	41	290 +	169		
35192	Standard Oil Co. N. J., Baltimore	442	166	103	72	48	283 +	132		
35082	Shell Oil Co., Martinez, Calif.	452	260	140	96	67	157	63	210	
35229	Gilmore Oil Company	456	223	133	87	57	158	79	250	
36702	Mex. Pet. Corp., Baltimore, Md.	484	153	100	71	47	290 +	155		
36092	Standard Oil Co. Calif., Richmond	512	242	136	88	61	146	63	194	
36320	Standard Oil Co. La.	540	189	120	84	55	237	120	295 +	186
36344	Shell Oil Co. Norco	563	158	108	77	52	309 +	167		
36525	Associated Oil, Avon	570	316	159	105	68	126	52	160	
34496	The Texas Co., Port Neches	627	212	124	86	56	222	136	305 +	199
34273	Colonial Beacon Oil Co.	628	183	111	82	55	273	144	302 +	240
35116	Union Oil Co., Oleum	644	308	159	97	70	127	69	175	
36086	Mex. Pet. Corp., Destrahan, La.	653	187	115	83	59	266	136	292 +	198
35156	White Eagle	693	297	157	102	69	120	60	180	
36319	Standard Oil Co. La.	770	248	147	99	69	165	92	235	
36345	Shell Oil Co. Norco	846	228	133	93	67	238	120	298 +	195
36215	Standard Oil Co. Calif., El Segundo	960	501	213	129	90	85	41	121	
36353	Atlantic Ref. Co., Brunswick, Ga.	985	271	147	100	72	188	95	264	
36087	Mex. Pet. Corp., Destrahan, La.	1085	285	165	109	76	159	85	220	
35230	Gilmore Oil Company	1181	491	221	133	96	97	43	158	
36318	Standard Oil Co. La.	1248	403	190	124	88	126	65	169	
34495	The Texas Co., Port Neches	1293	491	221	131	88	110	61	162	

T. S.—Too soft for test.

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Hot Plant Mixed Asphalt Roads

By LARRY B. WEST, *President*
West Construction Co., Chattanooga, Tenn.

The Hot Plant Mixed Method of combining asphalt with mineral aggregate came into use sixty years ago—sixty years of use, and we must admit, sometimes of abuse, of any method should be proof of merit or of the dumbness of those that have continually followed it. As I have spent forty-three years of this sixty years following this method exclusively, I must, in self-defense, offer the Hot Plant Mixed Method as one of the best means for combining asphalt with mineral aggregate for asphalt road surfaces.

Public Demand

Conditions have changed in sixty years. The demands of the public who are paying an estimated average of one dollar for roads over which to operate their automobiles to every two dollars paid for gas—are reasonable and just. They demand Comfort, which means a perfect riding surface; they demand Safety, which means a non-skid surface under all conditions; and they demand Durability, at a very much reduced cost. This demand can be met with hot plant-mixed asphalt due to improvements in methods, increase in plant capacity, and improved methods of laying. Plant-mixed road surfaces have stood the test on the heaviest traffic streets of our country for longer periods than any other types of pavement. Records of service as great as fifty years have been known. An assured life of twenty years and longer on a properly designed and well constructed plant-mixed asphalt surface can be depended on.

Plant Mixed Asphalt Road Advantages

Following are reasonable claims in favor of plant-mixed asphalt roads, properly designed, and laid under specifications that meet the approval of our best Asphalt Technologists, with plants that will accurately carry out the design.

Asphalt combined with mineral aggregate, hot or cold, can be more accurately controlled by plant mixing than by any other method.

Grading of the mineral aggregate is an important factor in all asphalt roads, and better control of the grading can unquestionably be accomplished in plant mixtures where the mineral aggregate is screened to sizes and then accurately weighed.

Density is a proven factor for the durability of asphalt roads and greater density can, without doubt, be had with a plant-mixed operation where the grading with proper plant equipment, is used, and, wherein, the design of the mixture can be carried out to meet the traffic condition. High density in asphalt roads, so essential to durability, is only possible with plant-mixed asphalt.

Surfaces that secure the perfect riding comfort that people are demanding can be attained with plant-mixed asphalt when laid by mechanical finishing machines operated on side forms. By this method the capacity of large plants can be handled and the cost of laying greatly reduced over that of the old, inaccurate method of hand raking.

Spreader boxes give an even distribution of mixture on base direct from the trucks, and enable the plant to operate to a capacity of 80 to 100 tons per hour, which would be impossible by the old method. These spreader boxes also distribute the mixture evenly on the road so that the finishing machine can finish it to a perfect surface.

Non-skid surfaces on plant-mixed asphalt are a matter of preference of the engineer. These surfaces can be secured in the coarse type of mixture in the surface mixture itself, or they can be of pre-coated mineral aggregate of small size, applied and rolled into the surface, as originally recommended by C. S. Pope, Construction Engineer of the California Division of Highways.

Plant-mixed asphalt surfaces over old macadam, gravel or concrete roads produce the best results possible for comfort, safety and durability. On old or new foundations of gravel or macadam, temporary wood or steel forms are accurately

set to lines and grades, and on these forms the finishing machine operates, and screeds and finishes to a perfect riding surface.

With proper asphalt plant equipment there is little possibility of error in carrying out the designed mixture—with little or no variation in the grading, weighing and proportioning of the mineral aggregate, and in the automatic timing control for dry mixing, and then, further, mixing with automatic time control after the asphalt is added.

The temperature control should be within closer limits than heretofore, as uniform temperatures are helpful to laying.

Engineering Supervision

Not until you combine the knowledge of the professions of Civil, Chemical and Mechanical Engineering will you get the best results.

Not until you give uncompromising support to the Chemical Engineer will you get the best out of asphalt.

Not until you specify your equipment requirements, that will enable the Chemical Engineer to accurately carry out his design, will you get the best results in asphalt, nor will the Mechanical Engineer and the Manufacturer rise to the demand for better equipment.

The Cement Industry has been instrumental in giving us the finishing machine. The manufacturers have improved this machine for laying smooth-riding asphalt surfaces. Moreover, the cost, in connection with large asphalt plant productions, is less than one-half the cost of the old, inaccurate hand raking, which trusted to a man's eye the grading of an eighteen foot road or a forty foot street.

When asphalt meets with the success that it deserves, it will be through the combined and the co-operative efforts of three Engineering Professions, no one of which alone can meet with the same success.

The Civil Engineer has, and always will be, the Administrator and the Chief Engineer in control.

The Chemical Engineer should be the designer and supervisor of mixtures, but has been neglected in the design, testing and control of asphalt road work.

The Mechanical Engineer, in the design of equipment to better control and

more economically produce what the Chemical Engineer has planned, has received little encouragement from the asphalt industry. Where would the Cement Road Building Industry be today if it had not been for the combined and co-operative efforts of these three Engineering Professions? The Asphalt Industry can learn many valuable lessons from the Cement Industry.

Don't look for miracles, but pin your faith to what good Chemical Engineers have learned in the past sixty years about design and control in combining asphalt with mineral aggregate, plus what they can and will give you in the future if you will support them as they deserve. The failures in asphalt and concrete have been failures to use the services of good Chemical Engineers.

Combining asphalt with mineral aggregate is no more complicated than combining mineral aggregate with Portland cement, but to get the best results out of either asphalt or cement you must apply the experiences of the good Chemical Engineers of the past and present.

The Mechanical Engineer and the Equipment Manufacturers will rise to the demands of your specifications for accurate control as needed by your Chemical Engineer if you don't compromise on equipment requirements. Good tools and equipment are necessary to good work, and as much so in combining asphalt with mineral aggregate as it is in combining mineral aggregate with cement. Your specifications for accurate control of concrete and the equipment requirements are very rigid. Your equipment requirements on asphalt should also be rigid.

A questionnaire on the details of a contractor's plant and equipment for asphalt road building is equally as important as a questionnaire on his experience or his financial ability to carry on the work.

Specifications and Costs

Specifications should be drawn for the use of stone, granite, gravel, slag and sand aggregates, whichever may be locally and economically available, but when the design of mixture is fixed by the Chemical Engineer to conform to the local supply it should be carried out without compromise. Then, and only then, will you get the best in asphalt, because it is mechanically correct.

As to the cost, contracts with large tonnages secure the lowest prices, and asphalt plants with large capacities for lower prices on plant-mixed asphalt roads—plants coordinated to the capacity of a 4,000 pound pug-mill mixer, that are portable to the railways and that, also, can be moved away from the railroads. These plants, with capacities of 80 to 100 tons per hour, or 800 to 1000 tons in a ten-hour day, are extremely economical. One mile of finished plant-mixed asphalt wearing surface, one and one-half inches in thickness, laid by a finishing machine to a true, accurate, non-skid surface in a single day, is a possibility.

There is a big future for the plant-mixed type of surfacing. Heretofore, there has been but one reason against the mixing of accurately screened and weighed mineral aggregate with asphalt—either hot or cold mixed—and that has been the cost.

As to present cost, the following prices were bid during the past year.

The Mississippi Highway Department received bids on a 3" black base, 1½" sheet asphalt non-skid wearing surface, with pre-coated chips, laid over a gravel sub-base, at a price of \$1.05 per square yard, for the total 4½" of base and top.

The Alabama State Highway Department awarded a contract for laying a 3½" black base and 1½" Alabama Rock Asphalt wearing surface to a total thickness of 5" at a price of \$1.13 per square yard.

The North Carolina Highway Department received bids on a 2½" asphalt concrete wearing surface over a well-compacted sand clay and gravel roadway, the lowest bid on which was 42c per square yard.

The Ohio State Highway Department awarded a contract for a 2" non-skid hot mix surface, laid in two courses over old macadam, at a price of 38c per square yard.

These prices are low, but no lower than other types of roads that have been built during the depression and indicate what can generally be expected on asphalt road surfacing as well as on black base with asphalt top.

Danger in the Future

The danger of the future of asphalt has been demonstrated in the past and from it we should take warning. It is

folly to compromise with good workmanship and to fail to follow the information accumulated by Chemical Engineers for sixty years.

Expecting to perform miracles with asphalt and mineral aggregates by departing from the experience of the past without careful research and testing, has cost much in failure and has been extremely detrimental to the industry. Many mistakes have been made but few have been made under the guidance of good Chemical Engineers.

While I have never laid a square yard of concrete wearing surface, I admire the policy of the Cement Industry. They encourage research and testing. They support the Chemical Engineers, they back up the Civil Engineers, and they encourage the Mechanical Engineers and Manufacturers to design and build equipment for the better and the more accurate mixing and laying of the surfaces of concrete roads. When they secure the best that these three Engineering Professions have to offer, their specification requirements become standard.

The Cement Industry would not have progressed in road building without enlisting and giving support to the three Engineering Professions.

The Asphalt Industry has not given the support that the Chemical Engineering Profession deserves.

The Mechanical Engineers have received very little encouragement to design equipment for the better control of asphalt mixtures and the laying of asphalt surfaces.

The Asphalt Contractor

The Asphalt Contractor becomes an asphalt contractor usually through some figures he puts in a proposal, backed by a bonding company, and is not selected on his ability to perform his work, as engineers are selected. Unfortunately, contracts and bonds don't make contractors, but they do sometimes break them. Some time in the future perhaps it may be necessary for the paving contractor to show evidence of his ability in addition to his desire to make money.

Engineers have done much through questionnaires in the elimination of inexperienced contractors, and can do good by a questionnaire on equipment qualifications, and by not compromising on

the design of mixtures when established by good Chemical Engineers.

Experienced contractors respect the requirements of all good Chemical Engineers, knowing it means much to the future success of the industry.

Having passed the stage of believing that I am a successful designer of asphalt mixtures, I am content to follow the instructions of good Chemical Engineers. However, time, hard knocks, and working under the direction of good Chemical Engineers, have brought me to definite conclusions that are satisfactory to me.

Different mineral aggregates of the same grading by screen test, do not always successfully carry the same percentages of asphalt or filler dust. The fact that one carries less does not indicate that it is inferior. It may be very superior. Density attempted by the use of an excess of filler dust, often throws the grading out of balance, and the result is unsatisfactory. An excess of asphalt is as detrimental as too little asphalt.

The engineer who thinks he is getting his money's worth when he is getting all his specifications call for in asphalt and filler dust, often finds that his road is suffering from an over-dose.

Any well designed and properly produced dense mixture is always workable, and can be laid and compressed satisfactorily at temperatures around 300° F.; coarser types with more voids at lower temperatures. Uniformity in grading and temperature, and accuracy in weighing are necessary to good durable surfaces. Any lack of uniformity is usually due to plant facilities.

The allowable percentage of voids is dependent on the traffic of the road. Pavements designed for the extreme heavy traffic of our large cities, are not necessary for lighter traffic roads. To illustrate, we have laid some economically designed open surfaces of plant mix that are in good condition after twenty years. However, these same pavements would perhaps not have lasted twenty weeks under the heaviest traffic of a large city—and likely the heavy traffic type with its more expensive design would have done no better on these light traffic roads.

The seal coat on plant mixed surfaces should be abolished, as it causes the surface to become slippery. A mixture that

needs a seal coat is not good enough in itself to be laid. Non-skid surfaces should be made in the asphalt plant, so that they will remain non-skid—preferably through the entire wearing surface.

Accurately spreading, then uniformly compressing the surface mixture by mechanical tamping instead of rolling, and afterwards finishing to a true, non-skid surface, is a future problem in design for the Mechanical Engineer.

The maintenance on plant-mixed asphalt roads is always adding to the value of a sound investment. Also, you can add thickness and width as the traffic demands without sacrificing any of the original investment—and small repairs, when necessary, can be with cold mixes.

The Future of Asphalt Roads

The work the Asphalt Institute is doing for the betterment of asphalt roads should be appreciated by, and have the support of, all engineers and good asphalt contractors. But what has been done is not sufficient. It is the duty of the asphalt industry to make sure that no asphalt work is improperly done. Good work will be the greatest advocate for asphalt roads.

See that the specifications are right. See that the design, with the mineral aggregates available, is right.

See that the proper equipment is used, and the result will satisfy the people in comfort, safety and durability, and you will have built up a demand for the use of asphalt for roads that is permanent.

The Future Success of Asphalt Roads

My conclusion is that the future success of asphalt roads depends on:

1. Combining asphalt with mineral aggregate under perfect control in the asphalt plant.
2. Following the Chemical Engineer's advice and giving him 100 per cent support in carrying out the design of his mixtures.
3. Offering opportunities through your specifications to enlist the interest of Mechanical Engineers and Equipment Manufacturers.
4. Enforcing specifications as to the design of mixture and the plant equipment, and the laying equipment.

MAY 7 1934

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Road Mix with Macadam Aggregates

By O. W. MERRELL

Director of Highways, State of Ohio

The use of "Bituminous Material" on the Ohio State Highway System had its inception in 1909 on the South High Street Experimental Road south of Columbus, Ohio. Since that time the mileage of bituminous roads has become quite extensive. For instance the gallonage of bituminous materials used on the Ohio State Highway System has increased from a few thousand gallons to over twenty

million gallons per year at the present time, exclusive of bituminous concrete and pre-mixed materials. In addition to this the counties use as much more on the county systems of roads of which 24,000 miles are improved. In order that you may have a clear picture of the growth of bituminous roads on the Ohio State System the following mileage at the end of 1931 is given:

Water Bound Macadam (surface treated)	1,207 miles
Bituminous Macadam (penetration)	1,617 miles
Bituminous Concrete	285 miles
Sheet Asphalt	50 miles
Rock Asphalt	161 miles
Traffic Bound Surface Treated	1,501 miles
Traffic Bound Bituminous Dust Layer	1,526 miles
Total	6,347 miles

In addition to the above there are 1,500 miles of brick and 2,412 miles of concrete that require crack filling, patching and treating as necessity arises. This year approximately 600 miles of road mix and pre-mix surfaces have been constructed on the State System.

The large mileage of macadam and traffic bound roads as indicated shows the necessity for the development of some type of low-cost hard surface, that is mudless, dustless, smooth, non-slippery and that can be rapidly constructed. In the early development on traffic bound roads, skin treatments and mulch treatments were utilized. These proved to be inadequate in most cases.

The further development of this type resulted in the "road mix with macadam aggregate" or so-called "retread" or "mixed-in-place bituminous course." The road mix is being utilized now not only on traffic bound roads but on macadam roads and other types as well. A large

mileage of old, rough, narrow macadam roads has been widened and a new surface of "Road Mix" constructed in the last two years on the Ohio State Highway System.

In the construction of these roads Ohio is well blessed with materials, as there is an abundance of limestone, gravel and slag, together with numerous facilities for the refining of asphalts and tars. These materials are fairly well distributed and keen competition prevails.

The "Road Mix" type has proven to be more stable due to the fact that the aggregates are properly prepared, are free from fine material and dust and permit the use of a higher viscosity bituminous material. The quantity of bituminous material used per cubic yard of aggregate is more definitely determined and is kept to a minimum. Road mix is the open type. Its stability is dependent upon the interlocking of the particles in it and upon as heavy a bituminous binder as is commensurate with the mixing operation.

A Brief General Description of Road Mix

Road mix as we construct it consists of one or more courses, mixed-in-place, composed of properly prepared crushed stone, crushed gravel or crushed slag and bituminous binder, made by mixing one or more successive applications of bituminous material with a layer of aggregate spread upon a treated surface. The aggregate and bituminous material are mixed with suitable equipment until the aggregate is coated. The mixture is then adjusted to proper cross-section, grade and alignment. After it has set up sufficiently to become tacky, it is thoroughly rolled. After curing, one or two seal coats are applied, chipped and rolled. A tolerance of one-half inch in eighteen feet is allowed for smoothness. This tolerance is somewhat liberal.

The thickness of the various compacted courses are $1\frac{1}{2}$ ", 2", $2\frac{1}{2}$ " and 3", as may be specified.

Aggregates

The aggregates used are of crushed stone, gravel and slag of the following sizes:

In the $1\frac{1}{2}$ " course the allowable size is: 90 to 100 per cent passing a 1" (circular opening), 0 to 20 per cent passing the $\frac{1}{2}$ " and not over 5 per cent passing the $\frac{1}{4}$ ".

In the 2", $2\frac{1}{2}$ " and 3" depths the allowable size is: 95 to 100 per cent passing a 2", 70 to 95 per cent passing the $1\frac{1}{2}$ ", 40 to 70 per cent passing the 1", 0 to 15 per cent passing the $\frac{1}{2}$ " and not over 5 per cent passing the $\frac{1}{4}$ ".

The size of fine aggregate used for the seal coat is 95 to 100 per cent passing the $\frac{3}{4}$ ", 35 to 65 per cent passing the $\frac{1}{2}$ ", 0 to 25 per cent passing the $\frac{1}{4}$ " and not over 5 per cent passing a No. 10 sieve.

The modified abrasion allowable for stone and slag is: 2" size not over 24 per cent, 1" and $\frac{3}{4}$ " sizes not over 22 per cent.

The modified abrasion allowable for uncrushed gravel is: 2" size not over 12 per cent, 1" and $\frac{3}{4}$ " not over 10 per cent and of the crushed portion not over 20 per cent. The gravel shall be crushed so that the portion retained on the $\frac{1}{4}$ "

screen shall contain not less than 40 per cent fractured pieces.

Bituminous Materials

For the prime coat a light material is used with a viscosity (Engler) 50 cc. at 40° C. 10.0 to 20.0. For mixing either medium tar (viscosity Engler) 50 cc. at 40° C., 30 to 40 or 45 to 65 plus (the latter being used in hot weather) or Asphalt Cut Back viscosity (Engler at 50° C.) (first 50 cc.) 50 to 100 or 150 to 200 (the latter for summer use) or asphalt emulsion slow breaking 57 to 62 per cent asphalt specific gravity 25° C.—25° C. not less than 1.01, penetration at 25° C.—100 g., 5 sec. 100 to 225.

The bituminous materials for the first seal coat are a heavy oil specific gravity not less than 0.980; or heavy tar specific gravity 1.18 to 1.25; or asphalt emulsion as previously stated.

The bituminous materials for the second seal coat (drag treatment) are asphalt cut-back asphalt emulsion, or medium tar as previously described.

It is impossible to give the amounts of bituminous materials used for the various depths of aggregates in this paper. Some aggregates due to their characteristics require more than others. Most slags will require from 25 to 30 per cent more than stone or gravel. I will give, however, the amounts for a 2" depth of stone. The amount of stone in the mix is approximately 135 lbs. per sq. yd. and for the first seal 12 lbs. and second seal 23 lbs. per sq. yd. The amount of prime coat .25 to .35 gal. of bituminous material per sq. yd. if needed. The first mixing operation .45 gal. and the second mix .40 gal. per sq. yd. The first seal .25 gal. and the second seal .25 gal. per sq. yd. The above totals 1.35 gal. of bituminous material per sq. yd. less the prime coat. For more detail as to the quantities, we will be pleased to furnish you a copy of our specifications. These qualities have been determined more by the cut and try method of actual experience than by an empirical formula.

Some details as to the method of construction are as follows:

Prime Coat

The surface should be thoroughly cleaned. All new surfaces should receive



A pre-mix asphaltic macadam, cold-laid, showing precision of finish and the non-skid surface texture



Finished Asphalt road-mix surface with macadam aggregates

a prime coat. Previously treated surfaces may not require a prime coat, although in some instances the surface may require patching or in all instances an old high crowned, wavy road should receive a wedge and leveling up course, preferably of a lean bituminous nature. At any rate the smoother the base, the better the surface will be.

Spread Aggregate

Upon the prepared base the aggregate should be spread to a uniform depth over the surface and to a width slightly less than that required in the finished job. With uniform spreading the proper amount of bituminous material may be more uniformly applied. The spreading is usually done through spreader boxes and shaped with a hone afterwards. Segregated material should be replaced.

Application of Bituminous Material and Mixing

The bituminous material is usually applied in two applications and mixed after each application although in the case of quick setting emulsions or asphalt cut backs it may be necessary to apply in one application. Uniform application and immediate mixing is highly important. The choice of mixing equipment, especially for large mileage, should be given careful attention. Blade graders, both pull and patrol were first used with a result of about one-half to one mile per day. This has been increased very materially by the introduction of the retread mixers and the multiple pin mixers. Once or twice over with one of these mixers is usually sufficient. Long stretches may be mixed without turning. The re-

sult is from three to four miles per day. The aggregate is thoroughly coated by these mixers and is spread to a true crown, grade and alignment. After the bituminous material has partially hardened or become tacky, it should be rolled. It is imperative to use sufficient rollers to thoroughly compact the mix at the proper time. In determining the proper time, experience is the only criterion as to when to roll with the various bituminous materials and aggregates under various climatic conditions. After rolling, all uneven places should be repaired.

The compacted mix should be allowed to cure as long as possible before sealing. We prefer to broom into the open surface a small amount of one-half inch chips. Then apply a seal of heavy bituminous material followed with a light coat of chips, finally rolled at the proper time. The chipping keys the surface and has a tendency to hold the heavy bituminous material in the top.

The second seal coat may not be necessary at the time of construction. A lighter bituminous material is used so that this seal coat may be dragged in case of a rough surface. The second seal coat seems to put on the finishing touches and give a riding surface highly desirable.

In conclusion it would seem that this type of road which carries a very high volume of traffic satisfactorily is becoming more and more important. This is due to the large mileage of roads yet to be constructed and others to be reconstructed. The rapid construction and the low cost of this type surely fit our present financial condition. It meets the problem of our farm-to-market roads and increases the effectiveness of our efforts towards agricultural rehabilitation.

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SPECIFICATIONS

FOR

LIQUID ASPHALT PRODUCTS

By

E. F. KELLEY

Chief, Division of Tests, U. S. Bureau of Public Roads

*(Paper presented at Tenth Annual Asphalt Paving Conference,
New Orleans, La., December 5-9, 1932)*

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Specifications for Liquid Asphalt Products

By E. F. KELLEY

Chief, Division of Tests, U. S. Bureau of Public Roads

Previous reports¹ concerning the cooperative effort of the state highway departments, the asphalt industry and the Bureau of Public Roads to simplify and standardize the specifications for liquid asphaltic road materials, have described in detail the procedure which has been established for carrying on this work, the program which has been followed and the progress which has been made. In these reports it has been pointed out that the cooperative program is divided into two parts; first, the simplification and standardization of the form of specifications by the adoption of a limited number of rational tests and the elimination of variations in test procedure; and, second, the standardization of the specifications themselves by agreement on the test limits to be specified for the grades of material which may be required.

Sufficient progress has been made in the first part of the program, the adoption of a simplified and uniform scheme of analysis, so that steps toward the adoption of standard specifications may now be undertaken.

The accomplishment of the second series of regional meetings, which was held early in 1932 for the purpose of considering the proposed scheme of analysis, was most encouraging both from the standpoint of the adoption of tests included in the scheme and the elimination of others. While we are still far from any unanimous agreement, a very definite advance has been made which already has been reflected in the specifications adopted by the various state highway departments for use during the construction season of 1932. In some cases the action taken by the state repre-

sentatives at these meetings came too late to influence the requirements of the 1932 specifications. Therefore these specifications do not give an accurate conception of all that has been accomplished. However, a review of them is of interest since it affords at least a partial measure of progress.

For instance, fifteen states now specify methods of flash point determination conforming to those recommended in the simplified scheme of analysis. Eleven states which, in 1931, used the Engler test for specific viscosity, have now adopted the Saybolt-Furol test and a total of 28 states now use this test exclusively in preference to the Engler test. Twenty-seven states have accepted the cooperative distillation test for cut-back materials and three have accepted it for slow-curing products other than cut-backs although these three have not at the same time excluded the test for asphalt content. The asphalt content requirement, which is not included in the proposed scheme of analysis, is still retained for slow-curing materials by all states which use these products and, in four states, the requirement is still in force even for cut-backs.

With respect to the test for loss by volatilization at 325° F. the 1932 specifications indicate little improvement over those of previous years. Twenty-five states still retain the test for slow-curing products and only two eliminated it in 1932. For cut-backs four states have eliminated the test but eight still retain it. Eight states have dropped the test for solubility in naphtha and eighteen retain it. Three states have eliminated the requirement for

¹ Cooperative Research and Standardization of Low Cost Road Improvement, by Prevost Hubbard, Eighth Annual Asphalt Paving Conference, 1929.

Simplified Specifications for Liquid Asphaltic Materials, by E. F. Kelley, Ninth Annual Asphalt Paving Conference, 1930.

Progress Report on Cooperative Simplification of Tests and Specifications for Liquid Asphaltic Materials, by J. T. Pauls, Proceedings of the Association of Asphalt Paving Technologists, 1932. Rationalization and Simplification of Test Requirements for Liquid Asphaltic Materials, by E. F. Kelley and Prevost Hubbard, Public Roads, Vol. 13, No. 6, August, 1932.

paraffin scale but seven continue to use it.

The agreements which were reached at the regional meetings of 1932 indicated a degree of progress in securing uniformity which, in some cases, are in contrast to the progress evidenced by the 1932 specifications. However, as has been stated, these meetings came too late to influence all the specifications which were used during 1932, and we must await the 1933 specifications for complete confirmation of the action taken by the representatives of the states at the 1932 meetings. For example, thirty-six states have agreed to use the cooperative methods for determining flash point but only fifteen have actually done so. The record for the viscosity test is much better, since thirty states have agreed to the adoption of the Saybolt-Furol method and ten have indicated the probability of its adoption, while twenty-eight states are actually using it and excluding the Engler test.

The record for the cooperative distillation test for cut-back products is also good. Twenty-seven of the thirty-two states which agreed to accept this test are now using it in their specifications. Eight states agreed without reservation to use the distillation test also for slow-curing products. Of these, four did not use products of this character in 1932 and the other four have not yet adopted the test for this class of product.

Twenty-nine states expressed the intention of eliminating the requirement for specific gravity of original materials but, of these, only three as yet have discarded it. At least twenty-six states used the test in 1931 and the same number used it in 1932.

Twenty-four states agreed to eliminate the test for solubility in naphtha and nineteen have done so but, as has already been noted, eighteen states still retain the test. The 1931 specifications of nine states provided a requirement for paraffin scale. In the 1932 meetings six of these states agreed to discard the test. Three have now excluded it, but one state, which did not use the test in 1931 and which expressed the intention of eliminating it from future specifications, included it in the 1932 requirements.

Thus it may be seen that, while we

have not yet attained anything approaching complete uniformity with respect to tests and test methods, we have made very material progress toward this goal. The degree of approval which the proposed simplified scheme of analysis has received, after less than two years of study, justifies the expectation that eventually we shall reach agreement on some series of tests which will be uniformly acceptable. The advancement which has been made toward the attainment of this end has now brought us to the stage where it is desirable and necessary to proceed with the second part of the cooperative simplification program, the standardization of the specifications themselves.

The Bureau of Public Roads, for the work which is carried out under its own direction in the national forests and national parks, requires specifications for liquid asphaltic materials. Since the Bureau has endorsed the simplified scheme of analysis it became necessary, during recent months, to prepare for its own use a new series of specifications based on this scheme. At about the same time the Asphalt Institute became engaged in the preparation of a similar group of specifications for the use of its members. These two undertakings, begun independently but with a similar end in view, offered an excellent opportunity for cooperation in the adoption of uniform requirements which could be offered for the consideration of the state highway departments, and also for the consideration of the Federal Specifications Board and possible adoption for the general use of all departments of the Federal government. At the present time the Federal Specifications Board does not have specifications for liquid asphaltic road materials, and the adoption of such specifications is a matter of common interest both to the government departments and to the producers of asphaltic materials.

Advantage was taken of this opportunity for cooperation and, as a result, tentative agreement has been reached on the specification requirements for thirteen grades of liquid asphaltic products. The essential requirements of these specifications, and the uses for which the various grades are recommended, are summarized in the accompanying table.

PROPOSED SPECIFICATION REQUIREMENTS
for
LIQUID ASPHALTIC ROAD MATERIALS

E. F. KELLEY

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TEST REQUIREMENTS	MATERIAL TYPE												
	SC-1	SC-2	SC-3	SC-4	MC-1	MC-2	MC-3	MC-4	MC-5	RC-1	RC-2	RC-3	RC-4
Water and sediment, per cent.....	2.0 -	2.0 -	2.0 -	2.0 -									
Flash point, °F.....	150 +	200 +	200 +	250 +	40-150	150 +	150 +	150 +	150 +	80 +	80 +	80 +	80 +
Viscosity, Saybolt Furol at 122°F., sec.....	20-150	200-320											
Viscosity, Saybolt Furol at 140°F., sec.....													
Viscosity, Saybolt Furol at 180°F., sec.....													
Viscosity, Saybolt Furol at 240°F., sec.....													
Total distillate to 374°F., percent by volume.....		2 -	2 -	2 -	10 -	2 -	2 -	1 -	1 -	5 +	10 +	3 +	0.5 +
Total distillate to 437°F., percent by volume.....		15 -	10 -	8 -	25 +	10-20	8-20	16 -	14 -	12 +	20 +	14 +	7 +
Total distillate to 600°F., percent by volume.....		25 -	20 -	18 -	50 -	27 -	25 -	25 -	20 -	25 +	35 -	30 -	25 -
Total distillate to 680°F., percent by volume.....	50 -	25 +	25 +	25 +									
Float of residue, 122°F., sec.....	50 -				70-300	100-300	100-300	100-300	100-300	60-120	60-120	60-120	60-120
Penetration of residue, 100 g., 5 sec., 77°F.....		99.0 +	99.0 +	99.0 +	60 +	60 +	60 +	60 +	60 +	60 +	60 +	60 +	60 +
Ductility of residue, 77°F., cms.....					99.5 +	99.5 +	99.5 +	99.5 +	99.5 +	99.5 +	99.5 +	99.5 +	99.5 +
Solubility of residue in CS ₂ , per cent.....	99.0 +												
RECOMMENDED USES													
Dust Layer.....	X				X					X			
Primer.....													
Surface treatments.....													
Mixed-in-place construction:													
Aggregate densely graded ¹		X	X ³			X					X	X ³	X
Aggregate, open graded ¹													
Coarse aggregate ¹													
Plant-mixed construction:													
Aggregate densely graded ¹													
Aggregate, open graded ²													
Aggregate, open graded ¹													
Coarse aggregate ¹													
Coarse aggregate ¹													

¹ Max. size not over 1 inch. Fairly uniform grading from coarse to fine with appreciable percentage passing No. 200 sieve.

² Max. size not over 1½ inch. Fairly uniform grading from coarse to fine with little or no material passing No. 200 sieve.

³ Max. size not over 1 inch. Fairly uniform grading from coarse to fine with little or no material passing No. 200 sieve.

⁴ Max. size not over 1½ inch. Little or no material passing ¾-inch screen.

⁵ Under favorable conditions only.

Time does not permit of a detailed discussion of the requirements of these proposed specifications. Briefly, the thirteen grades of material are of three general types, namely, slow-curing, medium-curing and rapid curing. One of the slow-curing materials, Type SC-1, is recommended for use as a dust layer; one of the medium-curing products, Type MC-1, is recommended for use as a primer; and one of the rapid-curing materials, Type RC-1, is intended for use in surface treatments. The other grades of material are designed both for mixed-in-place and plant-mixed construction, with graded aggregates of both dense and open grading, and with one-size aggregate of the macadam type.

Laboratory studies carried on by the Bureau of Public Roads during the past summer, and reported at this year's meeting of the Association of Asphalt Paving Technologists by J. T. Pauls and R. H. Lewis, have indicated the desirability of a change in the simplified scheme of analysis with respect to the temperatures at which viscosity determinations should be made. It has been concluded that, where practicable, the value of Furol viscosity should be limited to a maximum of 500 seconds, and that the temperature of 140° F. should be used in the viscosity test for those materials which otherwise would be tested at 122° F. but whose viscosities at that temperature are greater than 500 seconds. It has also been concluded that, on account of the effect of volatilization of light constituents during the test, the viscosities of rapid-curing cut-backs, irrespective of their values, should be determined at a temperature not greater than 140°F., and that the maximum temperature for medium-curing cut-backs should be 180°F. These conclusions account for the use, in the proposed specifications, of the two temperatures, of 140°F. and 180°F., which were not included in the simplified scheme of analysis, and also for the high viscosity limits at 140°F. of the heavy grade, rapid-curing cut-back, Type RC-4. It has also been concluded that, for materials which properly may be classed as liquid asphalts, there is no need for a viscosity test at the high temperature of 210° F.

It is believed that the series of tests included in the simplified scheme of analy-

sis are in all respects equal, and in many respects superior, to any other series of tests which has been devised for the control of the quality of liquid asphalts, particularly cut-back products. However, neither the tests which have been included in the scheme, nor any of those which have been excluded, give all the information which is desired with respect to the quality of products of the slow-curing type. Materials of this character are produced from petroleum from many fields. The finished products are the result of different refinery processes and frequently a single product may be a blend of materials produced by different methods. It is generally recognized that there may be a considerable difference in the service behavior of materials of this class, furnished from different sources, even though they may all comply with the requirements of the most adequate specifications which we are able to write at the present time.

These slow-curing liquid products are used extensively in the construction and maintenance of low-cost roads and their quality is a matter of considerable economic importance since unsatisfactory quality may unduly increase maintenance costs by making retreatment or reconstruction necessary at too frequent intervals.

The ability to coat the particles of mineral aggregate, to adhere to them permanently and bind them together, and the ability to resist the disintegrating effects of the action of the elements, are qualities of the slow-curing liquid asphalts which are not determined with any accuracy either by the tests which have been commonly used in the past or by those included in the simplified scheme of analysis. These are essential qualities and we shall not attain the best and most economical low-cost road construction until we are able to define them with reasonable precision in our specification requirements.

During recent years a noticeable change has taken place in the types of bituminous highway construction which claim the greatest amount of attention. In the past the primary interest has been in the high-type pavements and the greater part of the research work which was done during this period related to highway surfaces of this type. At the present time the predominant interest in bituminous road ma-

terials is in connection with their use in the construction and maintenance of low-cost surfaces, and much attention is being given to studies of the characteristics which are required to insure the suitability and durability of the less expensive materials which are available. A number of the state highway departments, the Association of Asphalt Paving Technologists, The Asphalt Institute and the Bureau of Public Roads are all actively interested in investigations designed to develop more accurate information regarding the essential characteristics of the slow-curing liquid asphalts. It is to be hoped that the results of these investigations eventually will permit the use of relatively inexpensive products without danger of unsatisfactory results due to inferior quality.

The effort to simplify and standardize the specifications for liquid asphalt products is an undertaking in which producers and consumers have a common interest. It is one which involves many difficulties, since its success requires a complete re-

vision of the established opinion and the established practice of many individuals, both among engineers and among manufacturers. Under such circumstances rapid progress cannot be expected and it is not certain that rapid progress is even to be desired. Since we still lack accurate and conclusive information on important questions it is as well, perhaps, to make haste slowly. The important fact brought out by this brief report is that definite progress is being made and that, when all the difficulties are considered, this progress is most encouraging.

I take this opportunity of expressing the appreciation of the Bureau of Public Roads for the cooperation which has been accorded so generously throughout this work by the state highway departments and the producing companies. To the truly cooperative attitude, which has been evidenced since the inception of the project, may be attributed the degree of success which has been attained and the further advancement which is expected.

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DEVELOPMENTS IN ASPHALT ROAD EQUIPMENT AND ITS USE

A SYMPOSIUM

*(Papers presented at Tenth Annual Asphalt Paving Conference,
New Orleans, La., December 5-9, 1932)*

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INTRODUCTION

(From Minutes of the Proceedings)

CHAIRMAN BERNARD E. GRAY:

In presenting this symposium on Road Equipment, it is not implied that only manufacturers considered important are included herein, but rather that the authors were kind enough to take upon themselves the work of preparing the papers and also because their respective companies have certain features in their equipment which are believed to be of particular interest.

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Developments in Road Equipment and Its Use

By BERNARD E. GRAY
Highway Engineer, The Asphalt Institute

The rapid development of various kinds of mechanical equipment during the past few years for all types of road construction, stimulated by the need to accomplish such building in a relatively short time and at lowered costs, makes the discussion of this subject particularly pertinent at this time. Naturally, as the result of rapid growth, numerous varieties of the same kind of equipment have come upon the market and improvements in design have often been made before the original equipment had come into general use. Out of this large amount of machinery, there have come fairly standardized types for specific purposes, which have had the test of sufficient time to permit evaluation of their efficiency both in contrast with other equipment and with hand labor methods.

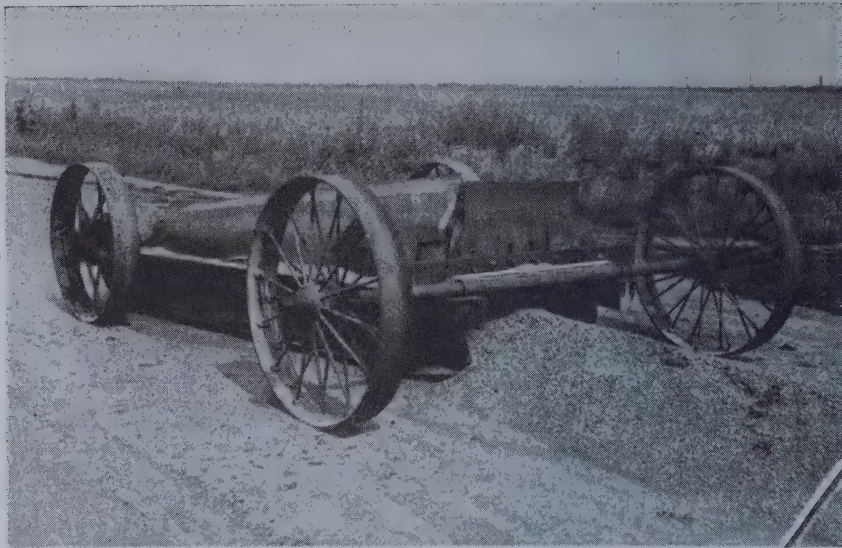
In regard to equipment and its relation to hand methods from the standpoint of its competition with and replacement of labor, it is not believed that the present regulations by some highway organizations restricting equipment are of anything but temporary character. This country has made its progress through development of machinery to replace tedious labor, and it is not going to discontinue its use just because there are temporary maladjustments in society. When, after twenty years of intensive road building, over seventy-five per cent of the national roadways remain still unsurfaced and only one farmer out of every four is located on a road usable the year around, it would seem rather absurd to curtail the use of equipment. It is confidently predicted that, within the next five years, we shall be using more mechanical equipment than ever before—much of it improved over present day designs—with the result that we shall have not only more comfort but also greater returns to labor as higher-priced jobs are provided in the handling of machinery.

The purpose of this paper is three-fold: to review the several types of road construction, particularly those of asphalt; to point out how the need led to the development of the equipment for doing each phase of the work, and to serve as the introduction to a number of short papers presented by leading equipment manufacturers, showing how their particular machines have been perfected to accomplish the desired results.

Out of all the discussions of road design, use of materials, traffic requirements, etc., there has definitely emerged the proposition that roads are best developed under some kind of a stage construction plan, building the surface adequate for traffic needs *and not overbuilding*. While the selection of type is dependent upon local conditions, there have come to be recognized four principal classes of improved surfaces using asphalt.

- I. Surface Treatments.
- II. Road-Mix Surfaces.
- III. Penetration Macadam.
- IV. Plant-Mix Surfaces,
 - (a) Laid hot.
 - (b) Laid cold.

For these types, certain equipment has been developed and, to those in the audience who recall work as it was done twenty years ago, there will be apparent quite a change in the present day procedure. All improvement has been based upon the attainment of one outstanding desired characteristic — Uniformity. A surface of uniform depth, uniform density, uniform smoothness, uniform texture and uniform strength will wear uniformly, with greater service to traffic and less maintenance. Accordingly, the gradual increase in use of equipment was not alone to secure lower costs but because a machine would accomplish work more *uniformly* than the most skilled labor.



*Machine for placing windrow of aggregate of constant volume.
Courtesy Kansas Highway Dept.*

With this in mind, the history of the several principal kinds of road machinery will be briefly reviewed followed by a brief comment on present practice.

First, and of primary importance, is the preparation of subgrade, which must precede any surfacing operation. There are many miles of highways which, if graded and drained on their present alignment, could be made entirely satisfactory for traffic by the addition of some form of low cost surfacing. Expensive grading operations are not required, but rather a smoothing, widening and ditching which will provide a uniform roadbed. Road graders have been used for many years; everyone present can remember the early types drawn by horses, but in their first use they were distinctly limited in what they could do, because of low power. The development of dependable tractors has probably had more to do in advancing low cost road construction than any other single item. With ample power available, and completely flexible in application, it became possible to make graders that would actually move dirt. It is not an uncommon sight today to see a few men with powerful tractor and grader, or power grader, actually widening roadbeds from twelve to eighteen feet or more at the rate of

miles per month. By the attachment of scarifier teeth, the machine can also be made to smooth old roadbeds. As a means of spreading aggregates, of mixing, of finishing shoulders, of ditching, and in numerous other ways, tractors and graders or combinations of the two have become indispensable. Numerous recent developments in this equipment will be presented later. They are used in every form of road surfacing later described.

I. Surface Treatments

The several steps in surface treatments are:

1. Preparation of surface.
2. Application of asphaltic material.
3. Application of cover coat.
4. Rolling.

The equipment originally used was a distributor and a roller. All other operations were accomplished by hand labor. The distributor frequently was an adapted horse-drawn water sprinkler having a spray-bar of pipe with holes at intervals, through which the asphaltic material trickled down on the road surface. Sometimes it covered and sometimes it didn't. If the horses were fresh, the rate of application was one amount and if

they were tired, it was another. The rate varied with every change in the weather as the asphalt cooled and the holes in the spray-bar became clogged.

From the difficulties experienced, it was apparent that improvements must include ways of regulating the flow, of maintaining constant temperature and of controlling the speed of the distributor. The change from horse-drawn to motor-driven distributors was a big step ahead. The use of heating coils and spraying under pressure eliminated further difficulties, while the addition of pneumatic tires, together with high-speed motors, greatly increased the range of the equipment. Next, someone asked the question: "Why waste time hauling the asphaltic material from the tank car to the job?" There then developed the plan of servicing the distributor by hauling material to it in a fleet of trailer tanks so that, except for a few minutes lost in transfer, the machine kept constantly distributing. The most recent development goes one step further and in effect says: "Why transfer the material from trailer to distributor?" On some long western jobs, where materials required little heating, the distributing equipment consisted of a four-wheeled light chassis on which were mounted spray bars, tachometer, compressor and pump, with a slip connection so that it could be attached to the trailer tanks as fast as they came to the job and thus apply the asphaltic material direct.

These developments have made large scale operations rapid and effective, but in the meantime the small user has been by no means neglected in his needs. The miniature type distributor, embodying all the good features of standard sizes, of about 300 gallon capacity and made readily mountable and demountable for a number of makes of light trucks, affords every community, no matter how small, the necessary equipment at reasonable cost to take care of its local needs.

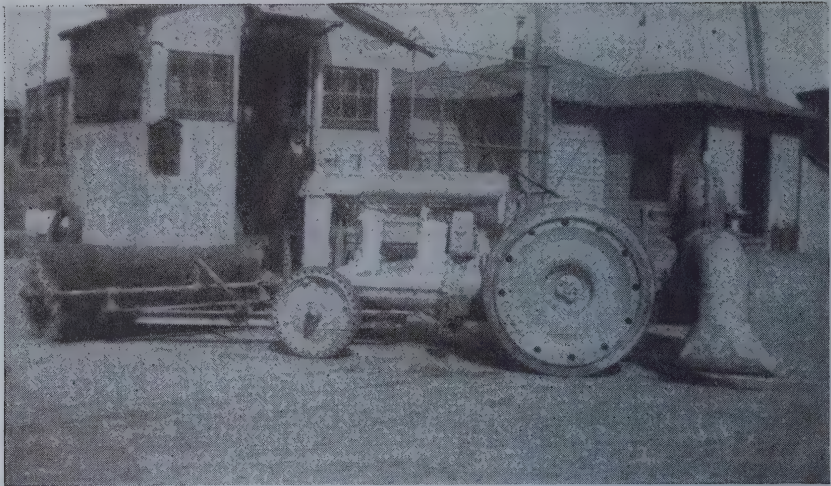
The hauling of cover-coat aggregates was a hand labor job until quite recent years, both for loading and unloading in bulk and for applying in small amounts to the road surface. As the distributor was improved, it became evident that its output was strictly limited by the slowness of handling aggregates. Once the need became evident however, the remedy



Trailer distributor for attaching to truck tank carriers. Courtesy Missouri Highway Department.

was near at hand, and so the small portable conveyor for unloading cars and for loading trucks began to be increasingly used. So now aggregates can be accumulated in large amount and stock-piled, ready for quick transfer to trucks when work is ready, whereas formerly the cost of rehandling by hand would have rendered the procedure prohibitive. In the same way with spreading aggregates over the surface; the old method required spotting small piles along the roadside. Sometimes there was too much, then again too little, with all of the difficulties caused by dirt, grass and leaves mixed with the aggregate. Everyone can remember the efforts made to train groups of men hastily assembled how to fan a shovelful of stone or gravel over the surface of the newly applied asphalt. Half the ridges in surface treatments were built into the road by faulty application of cover coat. Much of this drawback of hand labor may now be overcome through the use of a broom-drag, but the better way to insure superior results is by using some form of mechanical spreader which may be so attached to the truck as to permit rapid, uniform application of material.

In early work the roller was usually operated by steam. Most of the asphaltic materials used were those requiring heating, and the steam roller often served a



Road Blower used by the Virginia Department of Highways

dual purpose. With the gradual change from steam to gasoline power, the problem of heating became acute and finally led to the increased use of the so-called "cold asphaltic products." The desirability of using heavy treatments in many situations however, has led to the solution of this difficulty and today there are several highly compact, rapid heaters wherein a small condensing type of boiler is fired by gas torches so as to be far more efficient than the old style steam boiler and rapidly portable as well.

The roller itself has changed from the slow-moving steam type to the low-center-of gravity rapid moving gas type, with a much greater capacity. Smaller sizes have been developed for patching operations and these, by loading the wheels, may also be used for surface treatment work with good results.

The old horse-drawn sweeper was efficient but, with the improvement of the distributor and the handling of aggregates, it became too slow. Today the broom is on the front of a tractor and sweeping is rapid and accurate like all other operations.

As each phase of the work was speeded up, the other operations were studied and in turn improved, with the result that today, whether jobs be large or small and notwithstanding the higher level of prices for labor and equipment, surface treatment work is accomplished infinitely better and much cheaper than

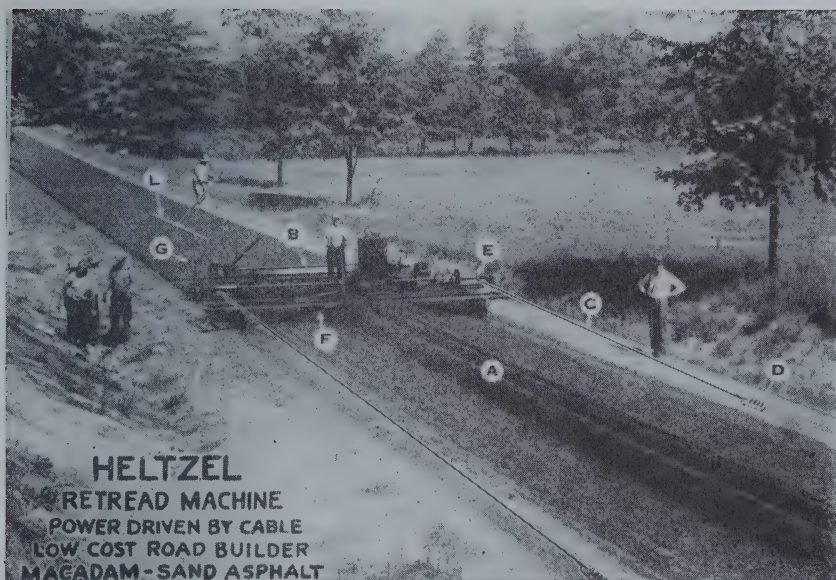
in the so-called "good old days" of twenty years ago.

II. Road-Mix Surfaces

This type is of comparatively recent origin. It was evolved from surface treatment when someone discovered that by dragging the cover-coat material a better and smoother surface was obtained. It was not long before it was further discovered that an appreciable thickness of surface could be constructed by using more asphalt and more cover, and from this beginning the widespread use has developed. There are five principal operations to road-mixing:

- (a) Preparation of roadbed.
- (b) Spreading of aggregate.
- (c) Application of asphalt.
- (d) Mixing.
- (e) Compacting.

The description of equipment used for operations other than mixing has been previously touched upon under Surface Treatments. It is this mixing operation which is the distinguishing characteristic of the type. In the earliest work, it was accomplished entirely by a blade grader. Because of the length of time required for repeated turning of the aggregate to insure thorough coating, the asphaltic material had to be relatively fluid, and as a result dried slowly with consequent delay in final compaction and a relatively small output per day. There also tended



- (A) Shows material in windrow which has been mixed in place by blading.
 (B) Rear final spreader and stone keying member does final crowning.
 (C) Steel cable approximately 300' long anchored at (D) and wound on drums (E) at each side of machine. Drums are operated in unison on straight-away, or can be operated independently to negotiate curves. All power driven.
 (F) V-shaped spreader and leveler which splits the windrow (A) and spreads the material out to the side runners, which are set to the desired width of road.
 (G) Adjustable screws to regulate height of spreaders. (L) Checking smoothness of surface after one pass of machine with a 10 ft. straight edge.

to be some segregation in sizes, which prevented complete uniformity. Then someone suggested a frame with several blades set diagonally, so that in one pass of the equipment the material was turned as much as by several passes of the grader, and the multiple blade grader thereby came into existence. There are several similar machines such as the pin-mixer, which works like a great number of small blades, producing a turning and mixing motion.

Another type of mixing equipment is an attachment for the front of a truck or tractor, consisting of a shaft with propeller blades which rapidly revolve and, picking up the previously sprayed aggregate, mixes against a grader blade immediately behind, which spreads the mixture over the road surface.

As the rapidity of mixing has increased, it has become possible to use much more rapid-curing asphaltic mate-

rials so that a mile a day of finished surface is becoming common practice.

III. Penetration Macadam

The same general type of equipment is used on penetration macadam work as for surface treatment and has been touched upon previously.

The operations are as follows:

- (a) Preparation of subgrade.
- (b) Spreading aggregates.
- (c) Application of asphalt.
- (d) Application of cover-coat aggregate.
- (e) Rolling.

There is one difference, viz—that in surface treatment work many liquid asphalt products are employed which require little heating, while in hot penetration macadam quick and thorough heating is essential. The booster heaters developed for this work are extremely efficient and have lowered costs and reduced delays greatly.

IV. Plant-Mixes (Both Hot and Cold)

There are many operations involved in plant-mix work and their proper coordination is of the utmost importance for rapid and efficient operation. They are principally as follows:

- (a) Assembly of aggregates and asphalt.
- (b) Heating (hot-mix) or drying (cold-mix) of aggregates.
- (c) Heating of asphalt.
- (d) Conveying and screening aggregates.
- (e) Batching aggregates and asphalt.
- (f) Mixing.
- (g) Hauling.
- (h) Spreading.
- (i) Finishing.
- (j) Compacting.

Asphalt hot plant-mixes have been used for street surfacing over a long period of years but it is only recently that they have been employed on a large scale on urban highways. Failure to use these highly durable types earlier for this purpose over a considerable mileage may be attributed directly to the lack of proper equipment. Their increased use has been stimulated directly as a result of the success of the road-mix types obtaining more uniform mixtures, yet retaining the smooth finish obtained with the road finishing processes.

The plant-mix types are of three distinct kinds—one, the hot-mix types, such as sheet asphalt and asphaltic concrete, mixed hot, placed and finished while still hot; second, the laid-cold types, such as Amiesite, Colprovia, Macasphalt, etc., which are plant mixed and have a delayed setting; and third, the liquid asphaltic materials with aggregates plant-mixed at low temperatures and laid cold. The equipment used for hot plant-mix in the assembly of materials, heating and mixing has been considerably improved in recent years, while high-speed trucks on pneumatic tires have greatly increased the radius of operations from a single set-up.

Likewise with the cold-laid types, plant operation has been greatly improved, so that products of high uniformity may be assured, that can be shipped for long distances, and yet readily spread, smoothed and compacted upon arrival at the work.

The third kind of plant-mix has developed from the graded aggregate type of road-mix, in order to obtain greater uniformity of the mixture, control of moisture conditions and the possibility of storage of large amounts of mixed material in anticipation of more rapid construction during periods of favorable weather.

As refinements took place in road-mix types, someone asked: "Why haul aggregates out to the road, apply asphalt and then mix? Why not do the mixing in a plant, and then haul out the complete mixture, where only spreading and compacting would have to be done?" It was tried and found successful and so in many sections, especially for graded aggregates, the plant-mix using high viscosity liquid asphalts which permit of early compaction is used on a wide scale.

Another variation of this plant-mix is where, instead of assembling materials at a fixed plant, the plant is operated over the road, picking up the aggregates from a windrow, proportioning and mixing them in a pug mill and depositing the completed mixture behind, where it is finished and compacted by blading and rolling, or by other mechanical means.

With the increased speed of motor vehicles, the necessity for smoother riding surfaces became more apparent: first, to save the road itself from the effect of impact; and second, because the public demands riding comfort. No material, no method of road-building will be successful unless it produces this smooth-riding quality and no type of construction, no matter how meritorious in other directions, can hope for success without it. To produce uniformly smooth surfaces requires a precision of spreading and finishing not obtainable by hand labor, and the most *important single development* in using plant-mixes has been the mechanical finishing equipment.

The use of hot-mixes for rural highways was distinctly curtailed until it was perfected. Even now the importance of this equipment is not generally realized. Upon its use depends the complete success of hot-mix types, and no work of any amount should be permitted upon a rural highway that does not call for mechanical finishing. With the need for constructing highway surfaces rapidly as well as smoothly, the slow rate of plac-

ing asphalt hot-mix by hand was intolerable. Someone asked: "If they can lay Portland cement concrete by mechanical means, what is there to prevent placing asphaltic concrete in the same manner?" So a finisher was adapted for the purpose, as an experiment, and finally perfected to the point where it will accomplish a character of work that could never be done by the most skillful hand labor.

This work it does so rapidly that the old style small-capacity plants could not keep it busy. It therefore became necessary to make bigger plants, so that today a properly balanced outfit will lay from 600 to 1,200 tons a day without difficulty.

The use of the mechanical finisher and big plants means the return of hot-mix construction on heavy traffic roadways at costs that will compete with any type. Through its use pavements of any thickness may be laid with a smoothness equal or better than other surfaces, and with a uniformity of texture and density which makes for long continual smoothness under the wear of traffic.

There are three kinds of finishers—one, running on fixed side forms of steel or wood; another running on its own forms, the finishing machine being supported on long runners which minimize the irregularities of the old subgrade, and the third on rollers. Each type has a place according to the local conditions surrounding each job.

There are two further improvements needed in connection with plant-mix work—one, some sort of tamping device which will produce the ultimate compression required for hot-mix surfaces, with reduction of rolling after the passage of the finishing machine; and the other, some cheap effective method of drying aggregates on the road prior to mixing in a portable plant, or prior to the road-mixing methods for that matter. A portable tamper for compacting asphaltic concrete in widening operations was very successful on several jobs in Ohio last summer.

In this discussion of different varieties of plant-mix, no preference for one type as against another is intimated, for the reason that such selection is governed en-

tirely by local conditions. Climate, subgrade conditions, amount of traffic, availability of aggregates, all have a bearing and the engineer must make his selection according to his own needs. But, whatever the type, it is essential that proper mechanical equipment be used that will produce a *uniform smooth surface rapidly and at low cost.*

Reconstruction and Salvage

Finally, there is the matter of reconstruction and salvage of old bituminous surfaces. Many of these were originally built with a rather thin section and under heavy traffic have become rough and uneven, although well stabilized in their new position. Various methods of successful resurfacing have been used by first patching out the depressions and then placing a wearing course. There are many instances, however, where this would be unnecessary, provided some inexpensive effective method of shaving the surface could be employed. To this end several machines have been developed, principal among which being the disk type and the rotating cutter. The first is the least expensive and already used on quite a scale, but nowhere nearly as much as its effectiveness would warrant. Equipment of this kind must be strong, easily hauled by truck or tractor, of long wheel-base and with positive cutting action so that, after repeated passes of the machine, a uniformly smooth surface is obtained. The surface so prepared can then be effectively reclaimed either by surface treatment or by any method of placing a uniform depth of wearing course. The expensive item of patching is eliminated and the surface remains smooth because the sub-base is smooth.

Other extremely important equipment, such as rollers, trucks, brooms, sweepers, etc., have not been discussed to any extent, not because they are not indispensable but simply because they have been standardized for so long a period that their use has become well established. It has been more for the purpose of presenting some of the new developments, together with the possibilities of further improvement, that this paper has been written.

Tractors and Graders

By H. M. KLEISER

Austin Western Road Machinery Co., Chicago, Ill.

From its inception, the blade grader has been identified with road construction. In its humble beginning, it was merely a flat piece of steel approximately 5' long, 10" wide and $\frac{1}{4}$ " thick, placed mid-way between the front and rear wheels of an ordinary horse-drawn farm wagon and operated by hand, using lever arms to raise and lower the blade. Its function was to smooth out the ruts and hoof marks after a road or trail had been used in wet weather.

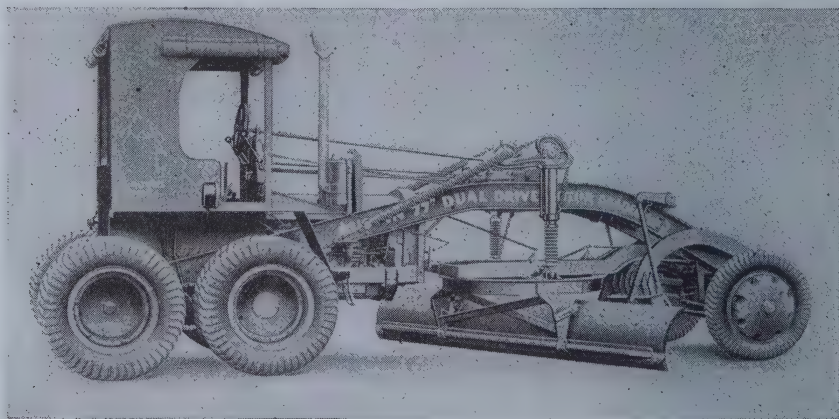
From that early beginning the grader has been improved, refined and re-designed until today it is a machine precisely manufactured, equipped with many attachments to broaden its uses and increase its capacity.

The grader has been a factor in the development of the tractor, from the first steam tractor to the powerful combination unit in use on every road construction job today. This is a practically universal piece of road equipment. Grading can be done, drainage perfected, sub-grade prepared, shoulders built, and the maintenance continued even after the road is turned over to traffic.

With the advent of the comparatively new and increasingly popular type road known as Bituminous Road Mix Surface, the tractor and grader was the first machine called upon to help improve and perfect the method of construction—preparing the sub-grade for the surface, spreading the aggregate and, after the asphalt has been applied, performing the mixing operation.

Recent improvements include: the substitution of a special oil-mix moldboard for the regular grader blade to give better mixing action; the equipment of graders with rubber tires, both solid and pneumatic; and attachments, similar to the pug mill, in front of grader blades, driven from a separate motor mounted on the frame of the grader. Other attachments are being given consideration by manufacturers at the present time in the hope of getting a quicker and better mix at less expense.

It is the belief of some engineers and contractors that the use of tractors and graders or motor graders in mixing the asphalt and aggregates is advisable. Because in the mixing operation the blade deposits a small amount of material in the depres-



Side view of the one-man power grader



Rear view of the one-man power grader showing the dual pneumatic drive arrangement

sion that occurs and the ironing action of the rubber tired wheels going over this tends to bring about a more compact subgrade on which to lay the finished surface. The ironing action of the wheels in the mixing operation, moving the material from 8 to 16 times across the road tends toward a more stable road.

The capacity of the tractor and grader or motor grader depends upon the tons of mixture per mile. The number of units used determines the speed of construction of the finished road. The cost of operation is in line with most methods in general use today.

Road Graders

By F. A. NIKIRK

*Civil Engineer, Supervisor Construction Sales,
Caterpillar Tractor Co., Peoria, Ill.*

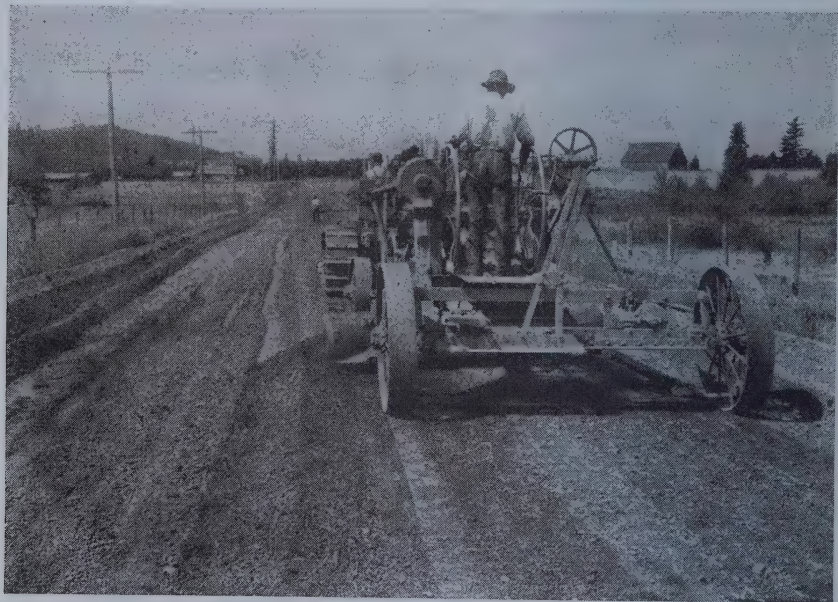
Economy in the treatment of our secondary road system points to the adoption of those methods that will utilize to the fullest extent the same type of equipment on each of the various stages of road development. That type of road equipment is the tractor and grader—used in the following stages of road construction:

1. In the original grading and draining of earth roads and for reshaping them when they become rutted from traffic.
2. In spreading and maintaining the graveled surfaces.
3. In widening and straightening the roadway as traffic demands.

The self-propelled type of grader has many advantages for those political subdivisions with highway systems of suffi-

cient size to have continued use for equipment on surface maintenance and from this demand has come the development of the Auto Patrol. Continued use under varying demands of road construction and maintenance have brought about developments in both the road grader and the Auto Patrol so that they will adequately perform the functions required in the oil treatment of road surfaces.

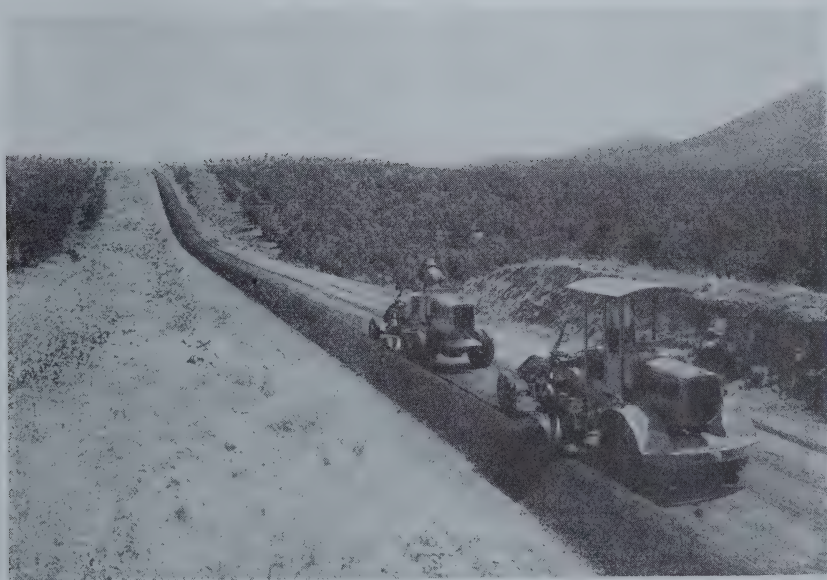
The requirements of this work are somewhat different from those of the original grading and draining of a road. In the first place, a bituminous surface is generally laid upon a compacted road bed. When rutted, this road bed must be planed off, usually to the depth of the bottom of the rut, and the grader to do this work must have sufficient weight to cut into



Roads can be built with tractor and grader alone in many instances



Even fairly deep cuts can be made with such equipment



Handling road-mix surfaces



Smoothing and consolidating road surfaces

the hard firm surface. The writer has long advocated the policy of using a *grader of sufficient weight to apply 500 pounds pressure per linear foot of blade* and still retain enough weight upon the wheels for proper guiding.

The grader should have a relatively long wheel base in order that the finished surface may be as free as possible from waviness. Some engineers are now specifying that a grader used on road-mix work shall have a wheel base of at least 16 ft. Other requirements include: rigid construction to eliminate chatter when passing over an uneven or corrugated surface; controlled blade action through gears amply protected from dust and working in oil; provision for take-up at all joints where wear may occur; provision for a scarifier that can be set to the required depth when the condition of the surface is such that scarifying is necessary; easy and accurate control of the blade and the scarifier, so that the operator can concentrate his attention upon the work he is doing.

Road-Mix Surfacing

In the early development of road-mix surfaces on the western coast the motor graders then in use were generally of the lighter type which did not provide either power or traction sufficient to mix a mat in excess of one and one-half inches in thickness at the desired speed. They were for the most part operated through open

gears and the dusty condition surrounding the preparation of the subgrade soon caused wear on these gears to the extent that considerable chatter of the blade and inaccuracies of its control resulted. These deficiencies have now been corrected and we have Auto Patrols for use in road-mix work that will handle a 10 or 12 ft. blade when mixing a mat up to 4" in depth and operating at a speed in excess of 3 ½ miles per hour. The blades used on road-mix should be somewhat greater in height for the corresponding length of blade than are used for ordinary dirt moving. To obtain the desired mixing action the blade should have the proper curvature that will cause the particles, as they rise toward the top of the moldboard, to fall forward with a cascading action, thoroughly intermingling the mineral aggregate with the binder.

Mechanical Improvements

Improvements, made by manufacturers to secure better balance of power, weight and traction, with increased strength to meet the increasing need of power, include: the protection of gears against dust and wear, thus eliminating play and chatter of the blade; increased ease of operation and accuracy of control of both the blade and scarifier; the development of the power control feature which allows the operator to concentrate his attention on the quality of work he is doing and places adjustments of the blade instantly at



Finishing plant mix surfaces

his command when such changes and adjustments are required; and, in cooperation with engineers engaged in road-mix work, the development of the road-mix moldboard.

All of these improvements have been made possible through the cooperation of the progressive manufacturer with the operator and the engineer in charge of the field work. Such manufacturers will continue in their endeavor. They have, however, now reached such perfection that excellent work is performed at the minimum of cost. The work of the engineering profession and the asphalt industry in collect-

ing and publishing information on materials and methods that will produce satisfactory road surfaces over a wide range of soil and climatic conditions is of the greatest value. They have recognized that these methods must be modified in different communities in order that native materials may be used to the fullest extent. When the methods adopted contemplate the use of the simplest type of equipment and that which is of the most general utility, the greatest economy will result—with the maximum extension of our secondary road system and benefit to the greatest number of taxpayers.

Modern Distributors

By W. E. WORCESTER
Vice-President of the Kinney Manufacturing Company

Definition

Any discussion of pressure distributors for the application of bituminous materials should start with a definition of a distributor, for strangely enough, there still seems to be considerable confusion on this point.

A distributor is primarily a machine for *applying* bitumen uniformly to the road in accurately measured quantities.

It may or may not be a machine that heats bitumen to the desired temperature to give the best results after it is applied, although in most modern machines this feature is incorporated into the construction and is of considerable economic importance.

As outlined by Mr. Gray, it may or may not be a machine used for the efficient transportation of the material from the tank car or other source of supply to the road. Here again this feature is usually found as part of the equipment except on excessively long hauls or in a comparatively few types of work where unusually large areas can be prepared for treatment in a day.

Pressure distributors as first used gave little emphasis to uniform application. Then, for fifteen years or so, this feature was quite generally stressed by some manufacturers and quite generally ignored by the engineers, some of them, possibly unwittingly, insisting on *uneven* application, or ignoring the subject with resulting fat and lean spots, ridges, and resulting disgust for various types of low-cost roads.

Even today, many of our leading engineers will take irregular distribution if by so doing they can save a fraction of a cent per square yard in the cost.

A modern distributor consists of a truck or a trailer, which is truck drawn, on which is mounted a tank with a heating system, usually oil-burning, with direct heat from the flue passing through the tank. The equipment is supplied with a

power-driven pump of suitable design to handle successfully materials ranging from light cold oils to heavy asphalts at temperatures from 350 degrees to 400 degrees F., together with suitable spray bars or manifolds and spray nozzles.

Design

The pump should be so designed that it supplies a constant pressure else there will be pulsation at the nozzles and cross ridges on the finished road surfaces. It should have sufficient capacity so that a quantity is pumped in excess of the nozzle output to insure the end nozzles getting a full supply. Otherwise there will be too light an application on the edges of the strip.

Quite incidentally, the pump should be so designed that it will take very sluggish material from the tank cars as frequently this saves costly delays in the work. High pump efficiency is of some importance as it cuts down operating costs for gasoline and results in smaller engines for operating and less dead load. The spray nozzles should be protected with strainers to take out coke and other foreign bodies, should be essentially non-clogging in design and easy to clean, and give a fan-shaped spray without streaks or "fingers" and no bare spots or ridges.

The truck, to be up-to-date, should have at least seven speeds forward—preferably twelve—and be capable of operating from approximately .8 miles an hour when on heavy penetration construction with quantities that are now regularly specified of 2.5 gallons a square yard 20' wide; and of road speeds ranging from 30 to 40 miles an hour when used for transporting the material considerable distances. The truck should be equipped with real brakes and must be equipped with a tachometer for the guidance of the driver in maintaining a uniform speed while applying the load.

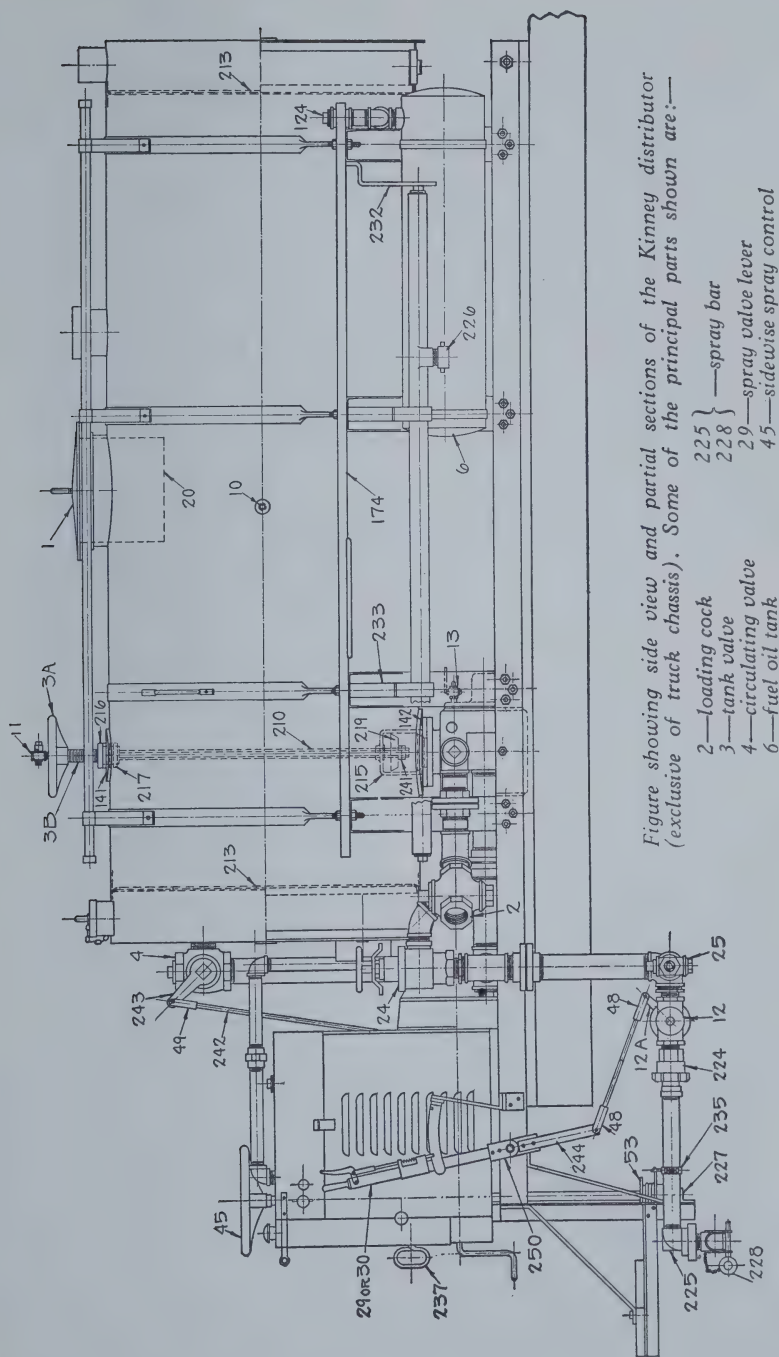


Figure showing side view and partial sections of the Kinney distributor (exclusive of truck chassis). Some of the principal parts shown are:—

- 2—loading cock
- 3—tank valve
- 4—circulating valve
- 6—fuel oil tank
- 225 } —spray bar
- 228 } —spray valve lever
- 29—spray valve lever
- 45—sidewise spray control

Speed and Pumping Capacity

The modern high speed machine has the pump driven by a separate power unit having no connection with the truck. The principle of design is based on pumping a definite quantity of material a minute to the road and then operating the truck at such a speed that this quantity is distributed over the correct number of square yards to give the desired quantity.

This design makes the use of a tachometer imperative, as a 20% variation in truck speed makes a corresponding error in the quantity applied a yard. Few truck drivers or engineers can detect by eye or instinct the difference between one mile an hour and .8 miles an hour, yet the error might result in the difference between two gallons a square yard or 1.6 gallons a square yard, with obvious disastrous results in the finished road surface.

A variation in the pump capacity gives the same sort of errors, hence it is important that the pump capacity be known and that the engine driving it be kept constantly in good mechanical condition and tuned up. Of course, if really competent operators are in charge of the machine, capable of some simple calculations, a variation in pump delivery due to wear, engine below speed, or changes in viscosity of the material handled, can be corrected by varying the application speed in the same proportion, but this usually means some cutting and trying, and a few strips put down in the road not in accordance with specifications.

The manufacturers almost universally supply the operators with charts as a guide, based on tachometer readings in fractions of miles an hour and pump capacity. This presumes the operators can read and are capable of simple arithmetic. In practice, remarkably accurate results are obtained where

- (a) The operators are competent and understand what they are doing.
- (b) Where the operators are honest and really intend to do good work.
- (c) Where there is intelligent engineering supervision.

Circulatory System

The heating system on most modern distributors consists of oil burners firing directly into flues surrounded by bitumen. Usually there is a hot spot of 2 or 3 feet from the firing end. If there is no circu-

lation other than the natural movement of the heated materials upward, a considerable quantity of material may be burned or coked at this point before the material at the farther end is hot enough to apply, with resulting raveling of the road, burned out tubes, and occasionally fires. Practically all manufacturers provide some mechanical means for circulating the material while heating and it should be used.

This circulation incidentally pays good dividends to the operator as fresh material is thus brought in contact with the hot tube surfaces and heats more rapidly. At the same time, when the material is of a uniform temperature, it applies more readily, there is less clogging of nozzles and pipes due to coke, and it produces a better road.

Secondary Uses

Distributors have many secondary uses, among which the more common are:

- (a) To transport cold patch material from tank cars to fill drums kept at stock piles at remote points.
- (b) To transport asphalt cement from tank cars or refineries to hot or cold mix plants located on the road away from railroads.
- (c) As pumping equipment, to transfer material from tank cars to storage tanks.
- (d) To transport water to be used in extinguishing brush, grass, and dump fires.
- (e) For hand hose patching, where penetration type repairs are required.

Costs

The cost of up-to-date distributor equipment varies with the size and type of truck, size of tank, type of insulation and accessory equipment with a range from the light truck with 350 gallon tanks at approximately \$2500, to 1700 gallon tanks and ten wheel trucks at approximately \$10,000.

The operating cost a day is somewhat higher than was the case with equipment in common use as recently as five years ago, due to the increased cost in license fees, more gasoline with high taxes, and pneumatic tires.

There is, however, a rosy side to the picture, since the production or output

has increased out of all proportion to the operating cost. This is, in part, due to the changes in distributor design but in large part to modern auxiliary equipment such as tank car heaters, stone spreaders, chip spreaders, power driven and tractor hauled graders, etc., so that no longer is the distributor regularly held up waiting for available road. In many states, programs for 1931 and 1932 called for three times as many gallons a day for each machine than could have been applied even seven years ago, and these production programs were usually fulfilled.

The records made by two different makes of distributors on mixed-in-place work in Kansas, surrounded by modern equipment and fed by supply trucks, each of which machines applied over 50,000 gallons of hot material in a day, and of dozens of machines that have applied from 8,000 to 16,000 gallons a day on widely varying types of construction and lengths

of haul are testimony as to the way that distributors have kept up with modern road building equipment.

The increased production is, of course, reflected in lower costs and bid prices. It is extremely difficult in a paper of this sort to intimate the cost a gallon of applying bituminous material, since so many factors enter into this which cannot be standardized, but the following points should be considered:

1. Capital cost of equipment.
2. Number of days each year work is available.
3. Probable weather and resulting delays.
4. Length of haul.
5. Grade of material to be applied.
6. Operators' wages and possibly living expenses.
7. Depreciation and obsolescence.
8. License fees.
9. Insurance and bond fees.

The Distributor

By F. E. WINTER
E. D. Etnyre & Co.

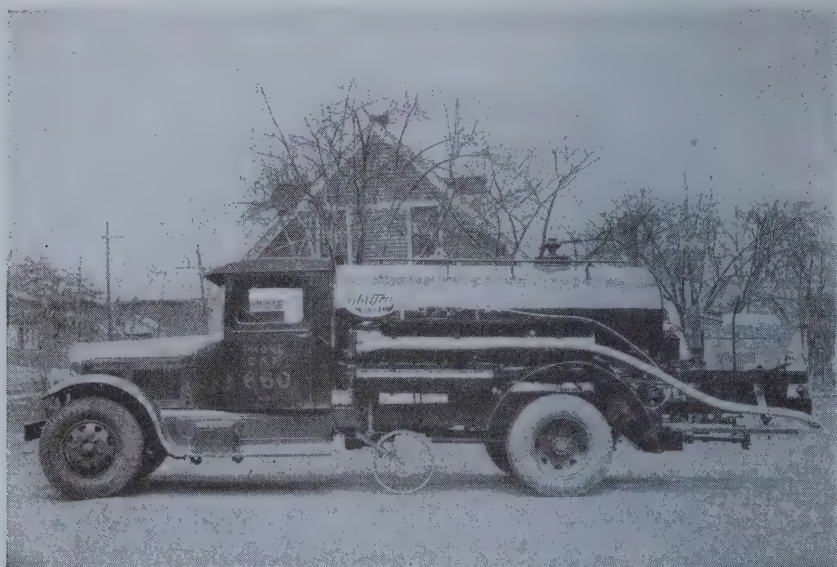
The functions or purposes of the modern distributor are: to apply, under pressure, any type of bituminous binding material, at the proper rate, uniformly and, in a great many cases, at certain specified temperatures.

Requirements

To develop and manufacture such a machine is not an easy task. To be a commercial success, it must be designed to handle any class of material, the lightest road oil, the various grades of cut-backs or emulsions, applied cold, and the heavier grades of materials, applied up to temperatures of 400 degrees F. It must be designed to apply those materials under sufficient pressure to give satisfactory results on either penetration or surface treatment work. It must be capable of applying those materials at any rate of application from .1 of a gallon per square yard to 3 gallons per square yard for various widths, and to do it in such a way that a uniform application of material is secured on each square

yard of surface. It must be self-contained in that it must be able to take its own load from the tank car or storage container, either by gravity or pumping, circulate and mix that load so as to secure uniform consistency, and unload itself, either by applying on the road or pumping back into the storage container. It must be able to take material at comparatively low temperatures and increases that temperature rapidly, without danger to the material, to comparatively high temperatures. It must be able to generate its own heat. It must be adaptable for mounting on any make of truck trailer or semi-trailer as it is mobile equipment. It must operate successfully in the mountains and the plains, uphill or downhill, under any condition of weather or temperature at which bituminous material may be applied.

Its basic design must be simple so that it is thoroughly understood by inexperienced operators. It must be easily serviced and maintained. It must be so constructed that while handling inflammable materials in



Side view of the Etnyre distributor. Note tachometer wheel separate from driving wheel, which can be raised up when not in use.

congested areas, it is at least reasonably safe from fire. It must be substantial in build so as to withstand the shocks to which construction equipment is subjected and, at the same time, it must be reasonably light in weight so as to have the greatest possible capacity commensurate with truck size, road clearances and allowable legal load limits. It must be equipped with appliances so that, at a glance, all interested parties may be able to ascertain the temperature of and the amount of material in the tank, and, when applying, the actual rate of application. It must start and stop application instantly. It must be manufactured in large or small capacities to answer individual requirements, but all sizes must retain all basic principles, as any size machine may be called on to make any application of material.

In addition to all this, it must be sold at a price which, in addition to the necessary profit, leaves a sufficient margin to carry on the experimental work necessary to keep the design abreast of the specification changes and advances.

History of Development

There are two general classes of distributors in use in the United States. The first, and by far the most general, secures

its pressure by means of a pump, while the second secures its pressure by means of an air compressor. The pump machines, again, are divided into two general classes. The first of these has the pump driven by a separate motor while the second has the pump driven through a power take-off from the truck motor. Owing to the varied requirements of application work, with the consequently varied pump speeds, and the necessity of making these applications under all conditions of road grades, the distributor equipped with the separate motor is fast supplanting all other types of distributors.

The present efficient design is the result, as is the case with all construction equipment, of long years of development. In the old days, those of you who were responsible for some penetration work which had to be done by hand with all its messiness and trouble, no doubt wished many times that someone would develop some way to overcome your troubles. Even at that time the development had started, but the most optimistic did not dream that it would be available for anything other than oiling work. In fact, the old water sprinkler was the first distributor and applied a light oil for dust laying purposes through the regular control valves, with gravity furnishing the only pressure. Then

someone conceived the idea of using a pipe with holes bored in line, which gave a more uniform application of oil. Even today, numbers of these outfits are seen, mounted on light trucks, applying dust layer with no other pressure than gravity. Subsequently, step by step was added the pump; first, a hand pump and then a rotary, driven by a chain from a sprocket wheel attached to the rear wheel of the sprinkler, the motive power being, in all cases, a team of horses.

At this stage, the increased use of the automobile, with the resultant destruction of the old type of untreated waterbound macadams, added stimulus to the development and we find the distributor mounted on a truck, consisting of a steel tank with kerosene burners underneath and a pump which was driven through a power take-off from the truck motor. Improvements were made from time to time but most of these old outfits were home-made affairs, fearful and wonderful to behold, the piping an intricate maze of pipe, nipples and fittings. Gradually the oiling industry was speeded up, heavier materials were being called for and finally the modern distributor in its earlier stages was sufficiently developed to the point where it would handle heavy materials on penetration work as well as the various surface treating products.

The next step was the change from the burners under the tank to the present form of return flues within the tank, through which hot gases were forced from generative burners, increasing immeasurably the heating efficiency. Later additional flues were added to take advantage of the heat still remaining in the gases before they were discharged into the air. It was about this time that the varied demands of specifications and topography, coupled with the usually low power of truck engines, made it necessary to add an additional motor for operation of the pump. Its success was so complete that practically no distributors of the pump type are built today without this supplementary motor.

Present Day Design

Today, practically all power driven pump machines are basic in design and consist of

1. The tank and its appurtenances.
2. The fuel and heating system.

3. The auxiliary power plant.
4. The distributing and circulating system.

All of these are mounted on a frame to form the distributor.

The tank, in which the bituminous material is loaded, heated and circulated, is either elliptical or cylindrical in shape, of from 400 to 1500 gallons capacity and of length to meet the ordinary variations of truck chassis design. It usually contains a gauge, visible on the outside, which instantly indicates the amount of material in gallons in the tank, and a visible thermometer which registers the temperature of the material. The tank is usually insulated with asbestos preparations, which insulation is in turn covered by a light gauge steel jacket to protect the insulation from the elements. Within the tank are located the heating flues. Most all makes have the large size return flues of 6 inch or larger diameter which pass through one head of the tank only. The other end of the return flues is supported by a frame within the tank. This frame should be of swing cradle design in order to properly accommodate the variations in length of the flue due to heat expansion. A rigid connection at the free end invariably causes trouble at the point where the flues are welded to the head. Supplementary flues of smaller diameter are usually spaced between the larger flues and the sides of the tank, and, unlike the larger flues, they extend through both heads of the tank where they are welded. Owing to the fact that they are not subjected to direct flame and heat but expand in harmony with the tank, little trouble is ever experienced with the welds of these smaller flues. It is only necessary to support them rigidly at the center to prevent vibration.

Generative burners are located at the lower entrance of the large size return flues and the hot gases from the burners pass through the larger flues, the full length of the tank and return to a small false chamber directly above the burners. From this point the gases pass through the smaller flues to the vent at the other end of the tank. In this way the heating gases pass three times the length of the tank before being exhausted into the air. The tank also contains a verticle overflow pipe which extends through both the top and the bottom of the tank. At the upper end this

overflow is covered by a dome in such a way that, when the tank is full, the dome prevents material from spilling when the distributor is going either uphill or downhill. The overflow also forms a vent for the admission of air when the material is being discharged from the tank. Usually some pressure relief arrangement is advisable in case of the formation of an explosive mixture within the tank. This safety in our equipment is accomplished by means of a friction ring held in the manhole casting on top of the tank. The inner side of the ring contains the threads which hold the manhole cover. In case of an explosion, ring and cover go out, relieving the tank without damage.

The burners are supplied with fuel from storage tanks which have sufficient capacity for a day's work. The kerosene fuel storage system, as a rule, consists of three tanks: first, a storage tank into which kerosene is loaded; second, a working tank which contains the kerosene under pressure; third, an air tank which contains air under pressure. The fuel is transferred from the storage tank to the working tank, under pressure, by means of a fuel pump which is driven by the pump motor. The air in the air tank is always available to build up air pressure as needed in the working tank. The distributor is also equipped with a portable burner attached by a long hose to the working fuel tank. This burner is useful in thawing out tank car connections and valves and in warming any parts of the distributing system when necessary.

The pump is the heart of the circulating and distributing system. On the modern distributor we find it located together with the motor which drives it either at the front end of the tank or at the rear, the pump being driven by the motor through a clutch and transmission with one or more speeds. The front end assembly is usually mounted cross-wise of the frame and is preferred by some manufacturers and users. On our equipment we locate the pump and the motor at the rear of the tank. By so doing we find that the center of gravity of the outfit is furthest to the rear when the tank is empty and moves ahead as the tank is filled; second, it permits the pump to be located directly underneath the tank in the line of the distributing system without the use of long intake pipes to the pump; third, the

location of the motor permits direct drive to the pump through the transmission; fourth, the location of the motor permits easy service to that unit.

Pumps on all machines are of the rotary type of which there are several styles. The most successful are those which have a maximum capacity with a minimum of weight, needed power, noise and vibration. They are usually rated at from 250 to 350 gallons per minute at high speed. As all material must pass through the pump when the distributor is either loading, circulating or applying the bituminous material, pressure is either secured by the type of construction of the pump or by building it up in the line by pumping against a pressure relief valve, which permits the flow of the material past the valve at certain set pressures. In our distributor, due to the construction of the pump and its location, we have been able to secure a uniform discharge of material per revolution of the pump for all free-flowing liquids at all pump speeds. This we have proven time and again through tests at the factory. This has permitted us to design a distributing system, without the use of pressure relief valves, which is positive in its action, uniform in its results and fool-proof in its operation.

Material is delivered from the pump through the control valves to the spray bars and nozzles from which it passes in the form of a spray to the surface of the road. Location of the pump with respect to the tank, lines and spray bars so that it and the entire system is self-draining is advantageous in that it tends to prevent the freezing of the pump due to congealing bituminous materials. Spray nozzles are, as a rule, of two general designs. One type is of the slotted variety, through which the material, when forced, makes a fan-shaped spray. The second type consists of two holes bored in such a way that jets of material forced through the holes impinge upon each other, thus forming the spray. Spray bars are usually designed to have the greatest cross-sectional area at the point of supply and gradually taper to the ends. This controls the amount of material so that each nozzle on the bar is supplied with its proper amount of material.

Refinements occur in various makes and models. Weight is eliminated wherever possible, welds and flanged connections

are preferable to fittings where the substitution can be made. Provision is made for the side shifting of the spray bars to overcome irregular driving and to meet longitudinal joints. On some machines the circulating system is entirely enclosed, which facilitates warming in cold weather, on others it is entirely open. Auxiliary equipment varies. Some manufacturers furnish everything complete, while others furnish just what is ordered. Some manufacturers design in standard sizes, that is, a distributor of given capacity has a tank of given length and diameters and must have a truck of a certain wheel base. Other manufacturers design the distributor to meet the needs of the customer's truck, varying the tank to meet the wheel-base and controlling the capacity by varying the diameter of the tank.

The distributing system should be as simple as possible. Controls should be banked compactly so that the operator will have no difficulty in performing his duties quickly and accurately. In the simplest type of control, engine speed is governed so that the pump speed is known. The pump delivers a certain number of gallons per revolution irrespective, practically, of the speed of the pump. With the spray bar width known, the gallons per revolution of the pump known and the speed of the pump known, a simple calculation will indicate the speed at which the unit must be operated along the road in order to make a given application. This speed is controlled in the driver's cab by means of a tachometer to which is attached a chart showing the reading at which the tachometer must be held to secure the proper application. The tachometer is 100 times as sensitive as the speedometer, the mark 100 of the tachometer being equivalent to 1 mile per hour, 200 of the tachometer—2 miles per hour, etc. It is driven from the speedometer shaft.

The ordinary crew consists of two men, a driver for the truck, and an operator for the distributor. The latter works on the rear end of the outfit. Some distributors have been designed and equipped to be operated entirely by one man, who handles both the truck and distributor. As a rule this is not successful for all classes of bituminous work and usually results sooner or later in non-uniform work.

Method of Use

On arrival at the car, the loading hose is connected to the outlet of the tank car and to the inlet pipe of the pump on the distributor. This latter connection is usually a snap connection. The motor is started, the valve in the tank car is opened, the pump is thrown into gear and within a few minutes the tank on the distributor is filled. Then the tank car valve is closed, and, after the pump has run a few revolutions to take the excess material from the hose, the connection to the distributor is snapped off. If no heat is required, the distributor is ready for application work. Motor and pump should be kept in operation for a time in order to circulate and mix the material in the tank.

If heat is required, the burners and fuel system should be examined to see that from 60 to 80 pounds pressure exists at the working tank. A little kerosene should be run into the pan at the bottom of the burners and lighted. As soon as the burners are properly heated they will roar, indicating that they are in operation. Flame should be regulated with the throttles and heating and circulating continued until the material in the tank has reached the desired temperature. In well insulated machines, temperature will be increased from two to five degrees per minute. Where heat is necessary and steam or heat boosters are available, it is better to heat the material in the tank car as much as possible and secure additional temperatures with the distributor heating system. If heat is necessary for the material, it is advisable to warm the pump and exposed piping, especially in cold weather.

On arrival at the work, the distributor should be checked to see that the proper spray bars are in place and that both the operator and truck driver are agreed on governor settings and tachometer reading for the application desired. The truck should be lined up in position a few feet behind the starting point so that the proper speed may be attained at the starting point of the work. If a joint is to be made, tar paper should be laid across the road so that the edge of the paper is at the point where material is to first strike the surface of the road. The word given, the truck starts and gains its desired speed and, as the spray nozzles come over the tar paper, the distributor operator throws

his control levers and the spray starts. Spray should be continued until the nozzles blow, showing that the tank is empty, and then shut off to prevent excessive drip. While applying material the distributor operator should watch the road edge or lap and operate the side shift so as to secure a uniform and even line. The truck driver should drive evenly and maintain uniformly the speed as indicated by the tachometer chart.

Irregular places of small gallonage are most easily handled by the hand spray nozzle, which can be snapped on or off at will. Its operation is controlled entirely by the distributor operator.

For best results, nozzles should be about nine inches above the surface of the road.

When through with the day's work, or when long intervals come between loads and the material has a tendency to harden, it is advisable to wash out the pump with kerosene by injecting it through the intake pipe while the bituminous material on the sides of the pump walls is still warm. This prevents the pump from freezing and the lines from clogging. A little heat applied to the spray bars also aids in preventing clogging of the spray.

Extent of Use

Originally used for surface treatment and penetration work, the distributor has come to be an important adjunct in all low-cost types of bituminous road construction. In addition to its ordinary function of treating surfaces, it is also used as a supply truck for furnishing bituminous materials to mixers on mixed-in-place work. I have known the distributor to be used for heating and applying brick filler. A short time ago we manufactured a combination spray bar containing a water passage way. Through this soapy water was forced out, striking the hot bituminous material just as the material met the

road surface, forming a partial emulsion at the road surface. One English firm has combined the distributor idea with a surface heater for penetration work. The machine works satisfactorily but the yardage accomplished is limited by the capacity of the surface heater.

As to the capacity of a distributor and its economy of operation, records and experience show a great variation. Certified records indicate that as high as 40,000 gallons of road oil have been applied by a distributor of 1000 gallon capacity in one day of twelve hours. To accomplish this, the distributor was supplied by trailers which carried the material from the tank car to the site of the work. Conditions of application, covering, weather and distance of haul from supply are all controlling factors.

Improvements out or to be announced soon, consist of new developments in spray bars whereby the material may be circulated in the bar itself before starting application. The shut-off is in the nozzle itself. This will eliminate clogged nozzles and drip on the road. New methods are being developed of attaching and driving tachometers so as to eliminate the wear of travel when the tachometer is not needed. Tachometer control of pump or pump motor has been designed with throttle control of the motor to eliminate any possible variation of engine speed and govern closer yet the application of material.

Road legislation is limiting the size of all mobile construction equipment and it is not thought that distributors will be made in larger sizes. Inquiries are numerous on trailer and semi-trailer types for special conditions, but the variability of demand on a distributor tends to limit that type of mounting. Greater capacities can only be secured by reducing weights with the future possibilities of building distributors of lighter metals.

The Evolution of the Bituminous Pressure Distributor

By CHARLES P. HVASS
President, Chas. Hvass & Co., Inc.

An important part in the production of the bituminous highways of today has been played by the pressure distributor. Without the numerous improvements in pressure distributors, the improvements in road construction and maintenance and in materials for that purpose would be unavailing and not productive of the desired results. Therefore, it is as essential to use the most modern and improved type of pressure distributor as it is to use the most modern methods and improved materials. The use of modern improved pressure distributors has not only produced the better road, but has done so in the most economical manner, resulting in low-cost bituminous roads. Therefore, it is as important for the highway departments of states, counties, and municipalities to use and to insist on the use of modern pressure distributors to produce the best results as it is for the contractors to use such equipment to obtain the best results in the most economical manner.

In the past pressure distributors which produced results far below the present requirements included:

(1) The trailer type drawn by a steam roller in which the steam pressure from the roller was injected into the tank for the ejection of the bituminous material.

(2) The trailer type drawn by a steam roller in which the steam generated in the latter was used to drive an air compressor on the distributor. The air under pressure was injected into the tank for discharging the bituminous material.

(3) The pressure distributor mounted on a motor truck equipped with a steam boiler from which the steam pressure was injected into the tank for the ejection of bituminous material.

(4) The pressure distributor mounted on a motor truck equipped with a rotary pump driven by a power take-off from the truck chassis propelling engine.

The effect on the bituminous material of the means of ejection of same from the tank, the abandonment of the steam roller

and the unequal distribution and quantity of bituminous material applied have resulted in the passing of the previously described machines, and the development of the present-day modern pressure distributor.

It is hoped that the following treatise on improved pressure distributors may prove helpful as a guide to those responsible for the preparation of specifications and requirements for the construction of bituminous highways, and in the selection of bituminous distributors by those who actually engage in complying with those specifications and requirements.

The modern pressure distributor is designed and constructed to accomplish the following results:

(1) To insure proper heating of bituminous material in the distributor tank in order to safeguard the material from coking and burning and to insure the proper temperature for application.

(2) To insure uniform application of the bituminous material in specified quantities over a variety of widths.

(3) To insure the safety of the operators, inspectors, road crews and others nearby when distributor is in operation.

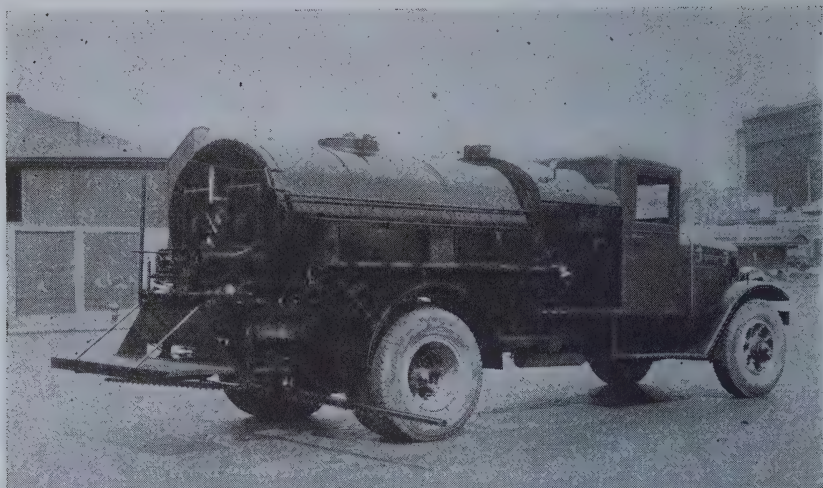
(4) To reduce to a minimum delays due to break-downs, improper heating and clogging of nozzles.

(5) To obtain safety while the pressure distributor is enroute to the scene of its work from the loading point while mounted on present-day high speed motor vehicles.

(6) To reduce to a minimum the time consumed in loading the distributor at the tank car or plant, and to do so with a minimum waste of material.

(7) To place the operator and the simplified controls in such a position that the application of bituminous material is under the operator's control and vision during the entire operation.

(8) To make possible the checking by inspectors of the results being obtained while the distributor is in service, and the adherence to specifications.



View of the Hvass Distributor

The foregoing results are obtained by the use of modern pressure distributors of the following specifications, which are made general in character to embrace the product of numerous manufacturers.

General Specifications of Pressure Distributors

Pump—The pump is of the rotary positive pressure type of sufficient size and discharge capacity to insure the application of specified quantities of bituminous material over specified widths taking into consideration available road speeds of the carrying motor vehicle. The pump is capable of applying from $\frac{1}{10}$ to 3 gallons per square yard in widths up to 18 feet. The pump is driven by a gasoline engine other than the vehicle propelling engine in the most direct method obtainable.

Heating System—The heating system consists of heat flues of sufficient radiation to insure the rapid circulation of hot gases of combustion from two efficient smokeless kerosene oil burners of the torch generating type. Provision is made for circulating the material in the distributor tank while heating to insure the proper heating of all material within the tank.

Tank Insulation—The tank is covered with insulation at least $1\frac{1}{2}$ " thick to prevent loss of heat of material within tank and to protect operators and others from burns due to contact with tank surface.

Tank—The tank is elliptical in shape in order to obtain low center of gravity of load when mounted on truck. The tank is equipped with removable manhole cover, 2" overflow pipe to carry any overflow from the top of the tank down through same to the bottom to spill under the truck clear of the exhaust pipe of same. This overflow serves as a gas vent to prevent any internal explosion within the tank. The tank is equipped with a strainer at the outlet to the pump in order to prevent the passage of any damaging materials. Heat flues for the proper distribution of hot gases are provided.

Miscellaneous Equipment

Spray Bars—Various lengths are required in order to spray material over widths varying from 4 to 18 feet.

Nozzles—The spray bars are equipped with spray nozzles of such design and size orifice as to insure uniform distribution of material in specified quantities.

Side Shifting Arrangement—The spray bars are arranged so that they can be swung from side to side over a distance of twelve inches to match the joints and clear obstructions.

Strainer—A strainer is provided in the discharge line from the pump to spray bars to prevent clogged nozzles and imperfect distribution.

Fuel Pressure Tanks—Suitable fuel supply and pressure tanks are provided to

insure the proper operation of the burners. The pressure tank is equipped with a pressure gauge and a relief valve set at 60 pounds.

Thermometer — A mercury actuated thermometer is placed in a suitable position at approximately the center of the height of the tank with a stem extending into the material.

Contents Gauge — A gauge equipped with a dial is placed in the center of the rear head of the tank to indicate the contents of the tank at various levels.

Pressure Gauge — A pressure gauge is provided to indicate the pressure at which the bituminous material is applied.

Hand Spray Nozzle — A suitable length of flexible steel hose with packed couplings, a hand spray bar and nozzle is provided for applying material at intersections, shoulders, etc.

Cut-Off Valve — A suitable arrangement of cut-off valves is provided and placed as close to the spray bars as possible in order to permit the operator to stop the application of material quickly and with a minimum of drip.

Hand Torch — A smokeless torch type fuel or kerosene burner with suitable hose and connections is provided to make possible the thawing out of pump, pipe lines, nozzles and bars before starting.

Pump and Piping Housing — A suitable housing is provided to enclose the pressure pump and piping to permit the heating of same to insure constant and even flow of material.

Pump Driving Engine Exhaust — The exhaust of the pump driving engine is piped to the spray bar headers and con-

trolled by a suitable valve in order to blow out the headers and nozzles.

Operator's Platform — A substantial operator's platform is provided at the rear of the distributor of such size as to enable the operator to have clear vision on both sides of the road while the distributor is in operation, and also to place all controls within operator's reach.

Filling Hose — A fifteen foot length of 3" flexible metallic hose with packed couplings is provided for loading the distributor from a tank car.

Tachometer — A tachometer is provided for attaching to the truck and is so located as to be visible to the truck driver to enable him to maintain the constant speed necessary for the correct application of the specified quantity of bitumen. Suitable charts are furnished to indicate the necessary truck speeds to obtain the required results.

The foregoing described pressure distributors are usually mounted on motor truck chassis. There is a recent evident leaning toward the use of large capacity distributors mounted on semi-trailers, drawn by a truck tractor.

The foregoing are submitted with the hope that they may prove helpful in the preparation of specifications covering the requirements of state, county and municipal highway departments covering bituminous pressure distributors to be used in the completion of bituminous road construction and maintenance contracts, and helpful to contractors in the selection of bituminous pressure distributors to fill these requirements efficiently and economically.

Equipment for Heating Tank Cars

By R. E. BROOKS
President, Cleaver-Brooks Co.

A modern steam heating unit for heating tank cars should embody the following features:

(1) *Fast Steaming*—A boiler which requires one to two hours to develop 100 pound steam pressure means a material loss in time both for men and equipment over a season's operation.

A modern boiler which is properly designed will produce 100 pound pressure from a cold water start, in as short a time as 30 minutes, with no damage to the boiler.

(2) *Portability*—In certain classes of asphalt surfacing, the work progresses rapidly, and it is therefore desirable to place tank cars to reduce long hauls. This may mean frequent changes of unloading sidings. The modern steam tank car heater is easily portable, mounted on rubber-tired wheels and equipped with roller bearings.

(3) *Water requirements as low as possible*—In many parts of the country, suitable water for boilers is almost impossible to obtain. The use of large quantities of bad water means increased boiler maintenance costs and lower efficiency. In many locations it means hauling water long distances in tanks at great expense. A steam plant for heating tank cars should, therefore, have as few steam losses as possible. The principal loss is ordinarily due to the practice of leaving a valve at the outlet of the coils partially open to "bleed" the coils free from condensation. This practice is costly both in water and fuel. A return condensate system should be provided which will efficiently return all the condensate from the car coils back to the boiler, thus saving water, fuel and liming the boiler tubes. Such a system will reduce the water requirements for heating a tank car from approximately 500-1500 gal. of water, to as little as 50 gallons of "make-up" water.

(4) *Low Fuel Costs*—Coal is often expensive and difficult to obtain. When hauling and handling costs are considered,

the expense is high. Fuel oil is available in tank wagons or drums in almost every locality. The modern steam tank car heater should, therefore, be equipped to operate on a low-cost fuel oil, bearing in mind, however, that efficiency and maintenance costs should be taken into consideration and should never be sacrificed in favor of a low-grade of fuel oil, particularly when the difference in cost of the oil may be but a cent or so per gallon.

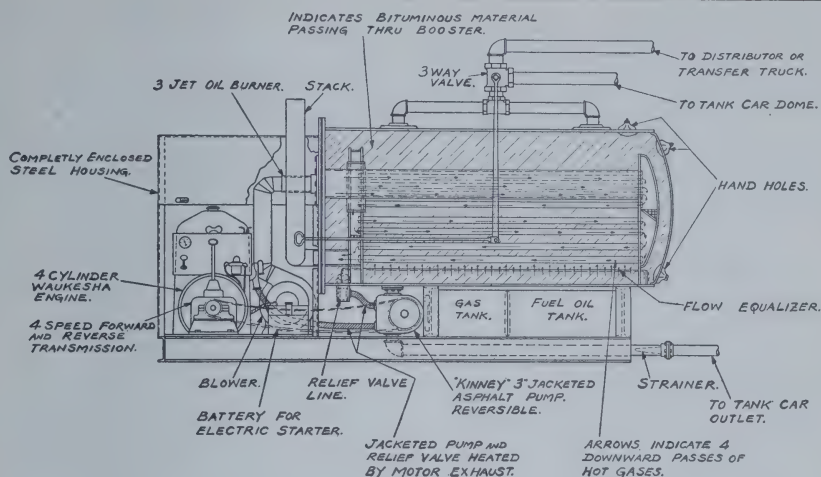
(5) *Ample Steam Capacity*—The average tank car has oil heating surfaces requiring from 12-15 Boiler Horse Power to properly heat the materials in the car. These coils are ordinarily built to stand 125 pound pressure, although many cars in service today will develop leaks under such a pressure. The lower the pressure the lower the temperature of the steam and hence the slower the process. The modern steam boiler for heating tank cars should be capable of maintaining at least 100 pound pressures and if it is to heat two cars at one time, should be capable of developing at least 30 boiler horse power.

Steam Heating Limitations

(1) Saturated steam at 100 pound pressure (absolute) has a temperature of 327.8°F. It will readily be seen that there is a loss in transfer from coils to material—and this loss is greatly increased if coils are not clean. It is, therefore, impossible to heat materials in a tank car to over 300°F. with steam at 100 pound pressure.

(2) *Heating Time Uncertain*: The reasons have been discussed above. On the average, with an efficient boiler and clean coils, it will be possible to raise the temperature of a 10,000 gal. car of material approximately 20° per hour.

(3) *Separation of Materials* — With some types of bituminous materials—particularly the cut-backs having large per-



CLEAVER
PUMPING BOOSTER.
CLEAVER-BROOKS CO.
135 W. WELLS CHICAGO, ILL.

Longitudinal section of Cleaver Brooks Booster

centages of distillates, there is a very great danger of separating the materials by still heating the tank car with steam. How serious this is in actual practice, we are not prepared to say, but it certainly seems logical to assume that in a still heated car containing a large percentage of light material, this lighter material would naturally rise and would tend to interfere with uniform application when pumped from the car.

Boosters

The booster provides a method of more rapid heating; (as high as 10,000 gals. raised 50° per hour), it eliminates all water, it enables the operator to withdraw and deliver a portion of the material in the car at application temperature, without having to heat the entire car to the required temperature, and it lowers heating costs materially.

The booster provides a unit capable of delivering required temperature material on short notice. Within a very short time after a tank car has been spotted it is possible to deliver the material into a distributor or transfer truck at the required temperature, thus eliminating many delays waiting for a car to be completely heated. To accomplish this result, the material in the car must arrive at a pumpable temperature, however. Practically all the road oils in most parts of the country, particularly

if shipped in insulated cars, arrive at pumpable temperatures. In many cases materials may be delivered in insulated cars at pumping temperatures if the request is made to the refinery or seller.

When materials do not arrive at pumpable temperature, it is necessary to steam such cars for a short time, and for this purpose there is available a unit known as the Cleaver "one car" heater.

Perhaps the outstanding advantage of the booster is the ease with which materials may be brought up to required temperatures. A dial thermometer registers the temperature of the material as it is discharged from the booster, in plain view of both operator and inspector.

The increased speed with which the materials are heated speeds up the entire operation and enables the handling of a greatly increased output with no increase in labor or other equipment.

Principle of Operation

The underlying principle of operation of the booster is the method of introducing the asphaltic material into the heating element, in such a way that the cool material comes in contact with cool tubes first and is gradually heated to the required temperature. This method prevents overheating or coking. The wide range of

pumping speed, plus the even wider range of B.T.U. development, by the use of either one, two or three nozzles, each of adjustable capacity, in the oil burner built into the booster, provides a heat control which is both flexible and absolute. The counter-flow principle built into the booster provides both high efficiency and positive control.

Design and Operation

Simplicity, ruggedness, and dependability are all built into the booster design. The four-cylinder gasoline engine which drives both the burner blower as well as the asphalt pump, is equipped with a four-speed forward and one reverse transmission. A pumping range of from approximately 30 to 350 gals. per minute is provided. The pump is of jacketed design heated by the engine exhaust. A three-way valve mounted at the outlet, enables the operator to pump from the bottom of the car through the booster and back into the top of the car or by delivering the material through a pipe, back into the car at a point sufficiently near the

discharge to provide efficient heating of the entire car and at the same time providing a circulation and agitation which prevents separation of the materials in the car. The construction provides easy means of cleaning and adjustment. By a simple header connection and an extra three-way valve, it is practical to provide a two-car hook-up, whereby one car may be heated and at the same time the material in the second car may be pumped into distributors or transfer trucks, thus eliminating any delay at the siding.

Capacity, Economy and Cost

The capacity of the booster is far beyond any similar heating plant of comparable operating cost. In general this unit will raise 10,000 gallons of bituminous material approximately 2°F. per gallon of fuel oil burned.

By the use of modern and highly efficient heating equipment, now available, it is possible to reduce operating costs, increase uniformity of output, and thus provide highways which more nearly meet the taxpayers' desire for value received for dollar spent.

Conveyors

By H. H. BARBER
Barber-Greene Co.

The term "conveyors" probably means belt conveyors to most contractors, for it is the type more commonly used in handling dirt, sand, gravel and crushed stone. We will confine this discussion to this kind of a conveyor and endeavor to show where and when it can be used to advantage and what kinds are best adapted for use in the road building industry; also discuss a few of the more important points of design.

In general, bulk materials are transported in two ways—intermittently as by wheelbarrows, trucks, cars, shovels, drag lines, etc., or continuously as by bucket elevators and belt conveyors. If conditions permit the use of continuous handling, it offers the cheapest way of moving large quantities of material. A small stream of material traveling at a high rate of speed makes possible large capacities with a low cost in power, labor, and investment. It is generally conceded that the belt conveyor is the most efficient or most practical type of conveyor for transporting materials continuously.

The belt conveyor is necessarily limited in its function. It conveys only and does not dig. The drag line is a tool that excavates and conveys, but we are finding that it often pays to transfer the bucket load to a belt conveyor, thereby limiting the travel of the bucket and confining it to the digging operation. A conveyor travels in a straight line and cannot go places or discharge over as wide a range as a truck. However, the tripper and the shuttle conveyor and more particularly the portable conveyors have greatly eliminated this handicap. The stacker conveyor plus portable conveyors permit huge piles to be stored over large areas at a minimum cost. The same equipment can be used for transporting the material from storage to railroad or plant. The conveyor is being used more and more for elevating road materials to bins. It should be operated at an angle of about 20° and necessarily requires

length to elevate. If there is room it offers many advantages over bucket elevators and hoisting buckets. Less wear and tear and consequently less shut-downs and less supervision. A conveyor will handle material from a hopper bottom car to storage bins or trucks with much less investment and operating cost than by a clam shell bucket.

Light portable conveyors can be quickly moved from bin to bin or car to car or several conveyors can be used and still effect great saving in handling materials from cars to bins or trucks. Movable field conveyors in gravel pits on skids or even one long conveyor can be moved as the excavation proceeds. Greater and greater lengths are being used.

In the coal mining industry, there is one conveyor system that carries coal five miles at a capacity of 10,000 tons per day.

We find the most extensive use of belt conveyors around the large permanent screening and crushing plant for both gravel and crushed stone. In recent years road contractors have used conveyors extensively for handling aggregates from railroad car to trucks or stockpile in connection with road surface treatment, penetration macadam and road mix surfaces. The advantages of speed, low cost rehandling, and cleanliness of aggregates, all make for improvement in quality of finished work.

The development of the portable conveyor and the semi-portable conveyors that are made up of standardized units has very greatly increased their uses around the temporary or portable screening, crushing, mixing and storage plants.

In the past, the use of this equipment was more of a problem. Each conveyor system was built special and required a lot of time for measurements, layouts, details and fabrication as well as erection. Today the contractor can get the more common sizes out of stock. They are built in sections easily erected and again quickly dis-

ASPHALT PAVING CONFERENCE, 1932



Barber Greene Belt Conveyor unloading crushed stone from railroad car to storage bins



Barber Greene Belt Conveyor unloading stone from railroad car to bin storage, and crawler loader handling sand to truck

mantled and set up for other uses. The conveyor is the loading end. A faulty lengths can be altered to suit. The owner looks upon his portable conveyor more as a machine capable of being used in a great variety of applications and over and over on each new set-up.

The design of portable conveyors is more difficult than the design of fixed systems. The structural work must be light weight, but strong enough to stand abuse. Maximum stresses are liable to come almost anywhere due to the handling and different set-ups. The belt must be kept in alignment and this done without rebuilding the structural frames every time they are moved. The manufacturer must produce this standard equipment so that it will handle all sorts of materials and conditions satisfactorily. Abrasive, fine, coarse, wet, hot, sticky materials are all handled on the same conveyor.

The carriers are very important elements in any conveyor system. Well designed ball or roller bearings reduce the power, wear and supervision. The added expense is not always justified in shorter length conveyors. Unless a bearing is high grade and well sealed against dust and grease, a good plain grease type carrier is more practical. A very vital place on a

construction here may ruin a belt in a short time. The life of a belt probably depends more on the manner in which it is loaded than on any other one factor.

The cost of building roads is largely the handling of great quantities of bulk materials. The profit particularly today will depend on doing this in the most efficient way,—and remember that continuous handling on belts usually is the cheapest way. Use them wherever possible.

In this particular field belt conveyors are used for handling almost every kind of material, including:

1. Sand
2. Gravel
3. Crushed Stone
4. Earth
5. Slag
6. Bulk Cement
7. Bagged Cement
8. Concrete
9. Muck
10. Brick
11. Oyster Shells.
12. Debris
13. Timber
14. Cinders

Portable Conveying Equipment in Asphalt Road Construction

By W. H. BOSWORTH

George Haiss Mfg. Co., Inc., New York, N. Y.

The modern plant used in asphalt road construction, whether it is the asphalt plant itself or the crushing or screening plant which prepares the mineral aggregate, would be hardly possible without belt conveyors and bucket elevators for handling the dry aggregates and sometimes even the mixed material. However, these conveyors and elevators are well standardized and are, in most cases, sold with the plant itself, so no further mention of them will be made in this discussion.

Independent portable conveying units are used in asphalt road construction to a considerable extent and their use is growing from year to year. As the value of asphalt road construction, both high type and low type, is recognized more and

more, the cost saving features of portable conveyor units make their use advisable and the stabilization of the demand justifies the increase in equipment inventories.

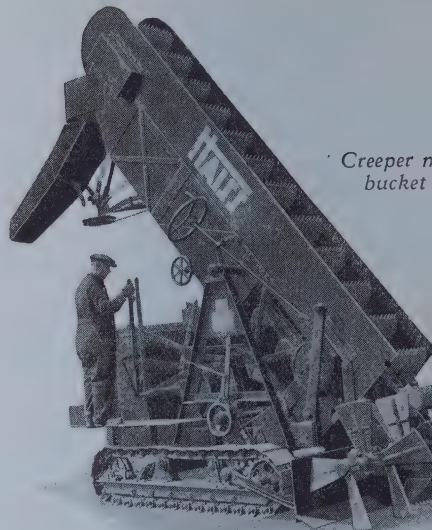
As to the effect on employment, it can usually be shown that the time saved by the use of such equipment is worth enough money to hire the men who are superseded and put them on other hand labor jobs which would not otherwise be done, such as trimming slopes, sodding, landscaping, etc. In other words, with a given amount of money available, the proper use of labor saving devices permits the employment of just as many men, and the accomplishment of more work.

Naturally, portable units are used to the greatest extent in the handling of drv

aggregates, although in some cases mixed material has been so handled. The most obvious use of a portable belt conveyor is in unloading dry materials from hopper bottom cars at the unloading siding or at the asphalt plant set-up, especially when the plant is a semi-portable one. The standard straight frame portable conveyor mounted on two wheels is ordinarily used. The belt width is 16 or 20 inches, the length of the conveyor 20 or 25 feet, 25 feet being perhaps better, as it permits piling the material higher and also, if loading into trucks gives a better trimming of the load, especially with the large body trucks now in quite general use.

Practically all conveyors used for this purpose have a troughing type of roller of one sort or another in order to give the maximum capacity without undue wearing of the belt due to abrasive material between skirt board and the rubber belt itself. We have found the most satisfactory type of idler to be made up of two straight pulleys mounted on a common shaft in a wide V-shape as avoiding friction between the belt and the pulley. This comparatively narrow belt width operates satisfactorily on a 2-pulley idler without undue breakage along the center line of the belt. We have found the use of anti-friction bearings in the troughing idlers and the tail pulley to be advantageous, causing less friction and standing up longer under service.

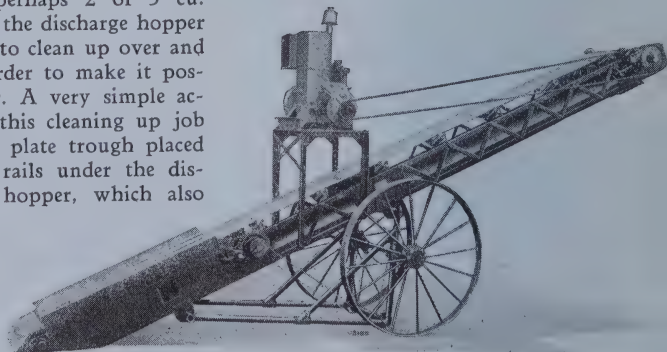
In many cases these conveyors are placed with the footshaft on the natural ground level at the side of the track, just alongside the discharge hopper of the car. A comparatively large proportion of the material in the car will fall by gravity onto the foot of the belt. It is, however, then necessary to shovel perhaps 2 or 3 cu. yds. from one side of the discharge hopper to the other and also to clean up over and around the rails in order to make it possible to move the car. A very simple accessory which makes this cleaning up job much easier is a steel plate trough placed over the top of the rails under the discharge point of the hopper, which also



Creepers bucket

means that a somewhat greater quantity of material will find its way naturally to the foot of the conveyor.

There have been developed under-car unloaders which are belt conveyors in special form for the purpose of doing away with the hand labor otherwise necessary for finishing the unloading and cleaning up. These are conveyors with very shallow frames which are placed over the rails sometimes with a straight discharge which calls for a small pit excavated under the end of the receiving conveyor of the standard type and in some cases with the discharge end inclined upward from the flat portion of the under-car unloader, so that such a pit is not necessary.



Portable belt conveyor

Another type of under-car unloader is one which calls for a slight amount of excavation under the track so that the conveyor can be placed under the rails instead of over them and with something more of a pit at the side in order to accommodate the tail end of the standard conveyor which is used for stock piling or loading. This type of unloader, while it calls for a certain amount of excavation, has the advantage that it does not have to be moved from under the car when the car is moved in order to give access to the material in the other discharging hopper, or when the car is moved out of the way and another car moved in.

When there is sufficient material to be unloaded at one point, and the ground conditions and railroad maintenance rules permit, it pays to dig a large enough pit under the track for a hopper and the foot end of the conveyor under the hopper. The hopper should have an adjustable gate to regulate the flow of material, and may be either a part of the conveyor frame or an independent structure. The conveyor is usually 30 or 35 feet long, and when the hopper is part of the frame, it is often provided with a 4-wheel chassis instead of the usual 2-wheel frame.

Conveyor Accessories

Accessories to conveyors for this job which may be of value are: A swiveling mounting for the two conveyor wheels, permitting the conveyor to be fanned about its lower end in order to increase the possible size of stock pile which can be built from one set-up, and another, an improvement in wheels which is comparatively recent, that of providing motor truck type wheels equipped with pneumatic tires so that the conveyor can be easily towed from one set-up to the next.

In conjunction with the long straight frame conveyor used with a hopper under the track, there are sometimes used loading hoppers as well as measuring and weighing hoppers for the determination of batches.

The conveyor frame should be rigid but light. A necessary feature of portable conveyors is that they shall be easily portable. The return run of the belt should be completely covered by sheet steel so as to keep any material which may fall over the side of the upper run of the belt from

lodging on the return and causing trouble at the lower end. Belting used should be of high quality as it will be found that the extra money paid for quality belting is more than made up by the life of the belting. We use a 4-ply rubber friction duck belting, 28 oz. duck on 16" wide belts, 32 oz. duck on 20" belts, with $\frac{1}{8}$ " rubber top and sides and $\frac{1}{32}$ " on the pulley side. For most purposes, gasoline engine drive is most satisfactory on account of the inability to get electric service in many locations. There are complete gasoline engine power units on the market built around small 4-cylinder engines which are so reasonable in cost that it is advisable to use such a unit with its additional reliability instead of small single cylinder units. With such a unit there will be furnished radiator, ignition, inbuilt gas tank and clutch and the unit should be equipped with an air cleaner on account of the dust prevalent around plants handling mineral aggregates.

Dependent on the amount of material which it is intended to handle at one set-up and upon the source of supply, it may be necessary to build stock piles higher than can be made with the 25 foot conveyor used for unloading hopper bottom cars. The same type of conveyor unit is available in lengths up to 60 feet for this purpose. About the maximum size which it is reasonable to move around is 40 feet long. With this a stock pile 17 or 18 feet high can be made.

Occasionally the mixing plant set-up will be such that the discharge from the mixer is too low to reach into the trucks, and in such situations the 25 ft. conveyor which has been described for car unloading work can be used for loading the trucks with mixed material. For this use it may be advisable to use a belt without cleats and with some scraping or revolving brush arrangement for cleaning the belt as it leaves the head pulley. In this kind of work a very important item is some method for keeping the tail pulley clean, as in spite of all the care which can be used, some of the material being handled will find its way on the inside surface of the belt and if of sticky consistency will build up around the tail pulley eventually to such a point that it will cause broken and tender spots in the belt. We take care of this difficulty by arranging a scraping plate on spring tension

which continually bears against the tail pulley.

A portable conveyor of the troughing type, equipped with a belt without cleats, will carry sand, gravel and broken stone, up an incline of 25 to 28 degrees, and with low cleats of belting material, up a 30 degree angle or 2 to 1 slope. For round gravel, all of about the same size, cleats 1" high of angle iron or V-type rubber belting will be more satisfactory if high discharge angle is desired. Of course, the use of cleats makes it impossible to apply a cleaning mechanism at the discharge end of the belt.

Portable belt conveyors range in price from \$600.00 to \$2,500.00, depending on the size.

While such portable belt conveyor units can also be used to advantage in loading trucks from stock piles, when the dry material is loaded in one spot and transported to another for mixing, it will be found that if fair quantities of material are to be handled, a self-propelling bucket elevator will be much more satisfactory and will pay for the additional investment in the saving in labor which results from its self-feeding ability as well as its ability to travel under its own power. Most satisfactory mounting for this type of loader is the creeper tread mounting, on account of the weight of the machine and the ability of the creeper treads to travel under almost any ground conditions. Where stock piles are small and some distance apart, there may be a call for a self-feeding bucket loader mounted on wheels, so that it can be trailed behind a truck from one small stock pile to the next. Such a machine is an intermediate piece of equipment between the portable conveyor, which can well be used for such purposes, and the larger creeper mounted bucket loader.

In some cases mixed material, especially for patching work, has been stock-piled and rehandled from these stock piles into trucks to be carried out on the road by a bucket loader. A bucket loader with a powerful digging and self-feeding device at the loading end will handle many such materials satisfactorily.

The greatest field for the bucket loader, however, is probably in handling of the aggregate material at the pit or quarry. In many gravel pits, particularly those which are used primarily for road build-

ing materials, the face of the bank is excavated by the loader. In many quarries loaders are used for loading trucks from ground storage piles, and particularly is this so with the screening piles for which apparently the greatest present use is for highways. The screenings are ordinarily waste in the production schedule of the quarry and are taken away from the plant and stockpiled on the ground where they sometimes accumulate for years. They make excellent topping material for seal coats as well as graded aggregate road mix surfaces and thousands of tons of screenings are loaded every year from these screening stock piles and used for such purposes.

For digging in the bank of the sand pit and for handling screening piles at quarries, especially when the latter have stood for a number of years, a positive digging and feeding device at the footshaft of the loader is a necessity. For this kind of work also obviously creeper mounting is strongly indicated. The small wheel mounted loaders of ten and fifteen years ago are not heavy enough nor strong enough to do this kind of work. The modern loader is a much improved machine and will prove to be the most economical machine for loading into trucks. It must be strongly constructed, with plenty of power, and with the parts of the equipment which come in contact with the material being handled, made of such abrasion-resisting material as 13% manganese steel. As much protection as is possible should be provided for transmission machinery in order to prevent expensive wear due to dust and sand which is unavoidable in such operations. Here the highest type of air cleaner is required on the engine as well as some type of cleanable oil filter for the engine oil.

Creeper mounted truck loaders are available for this kind of work in capacities ranging from 1 1/4 yd. a minute to 3 yds. per minute, in price ranging from \$2500 to \$5000. The amount of loading to be done will be the feature determining the size of equipment to purchase. It is to be kept in mind, however, that even on small capacities the larger machines will show a lower upkeep cost per yard of material handled, on account of the extra size of the parts and the better quality of material which will naturally be used in their construction.

W. H. BOSWORTH

In some localities the proper road material can be had from the natural bank without separating and re-proportioning. In some other localities proper materials can be had from the bank, but not in proper proportions, so that there is a demand for a loader and screen for taking out excess oversize material and excess fines. The capacity of a standard size loader is $1\frac{1}{2}$ to 2 cu. yd. or 2 to 3 tons per minute. To handle this output over a double deck screen of the highest type ordinarily requires a screen area of about 40 sq. ft.

There has been developed recently a

screening trailer to be used in conjunction with a standard loader on which is mounted a double deck vibrating screen 5 ft. wide and 8 ft. 6 inches long, and which is equipped with two side discharge belt conveyors, as well as an oversize discharge chute carrying the products of the screen to a proper height to discharge into trucks. This trailer is mounted on creeper tracks and is equipped with its own 4-cylinder gasoline engine. A great deal of interest has been evinced in this new development.

The price complete with screen is \$3500.00.

The Use of Multiple Blade Equipment for Road-Mix Surfaces

By C. F. BOYD

Manager of Sales, Galion Iron Works, Galion, Ohio

The various pieces of equipment manufactured by the Galion Iron Works and Manufacturing Company, Galion, Ohio, that are used in asphalt road construction are pull graders, patrol graders, rollers, multiple blade mixing and leveling machines and spreader boxes. The mixing and leveling machine together with a newly developed spreader box contain the more recent developments and design. I will take up the mixing and leveling machine as to its purpose and place in asphalt road construction.

The multiple blade drag was first used for traffic bound road maintenance. As the road-mix type of construction gained in importance and popularity among public officials and the traveling public it was readily seen that the principle of the multiple blade had possibilities as a mixer for this type of surfacing.

With these possibilities in view, The Galion Iron Works & Mfg. Company has developed its No. 20 machine. This machine consists of six moldboards or blades 20 inches in depth set in pairs which serve as mixing blades, one set of diverting blades, a strike-off blade, and an automatic edger. The entire machine is built around a rigid channel iron frame and carried on heavy axle and wheel construction. The machine is sufficiently adjustable to take care of any varying conditions that may be encountered on road mix construction. All operating devices are of the worm-screw type and are controlled from a single operating platform. Each end of the leveling blade is adjustable independently of the other, thus giving the operator control at all times of the crown slope. The automatic edger is adjustable in order to produce any desired thickness of pavement.

The purpose to be accomplished by the multiple blade mixing and leveling machine is to mix the asphalt and aggregate and in the same operation place the mixed aggregate to the desired cross-section. Its operation therefore follows the application of the asphalt on the aggregate.

The machine is pulled by a crawler

type tractor, the required size depending on the thickness or rate of application of the aggregate. The best results have been obtained by keeping the mixer comparatively close to the application of asphalt. In other words, the mixing should be accomplished at as near application temperature of the asphalt as is possible. The fact that this machine is simply drawn over the road leaves little for the operator except to keep the proper pressure of the blades upon the base and the slope of the strike-off as desired.

The main principle involved is in obtaining in one operation the same that may be obtained in several. The machine will not only produce increased mixing action but will also leave the paving course ready for rolling. Any asphalt that will lend itself to manipulation such as is required on road-mix contains certain ingredients that are necessary to keep the material workable until it is in place. After the material is in place this is of no further benefit. In fact, it may at times be detrimental in that the asphalt remains soft and pliable thus resulting in an unstable paving course. The mixing action produced by the multiple blade principle insures the uniform curing of the paving course to its full depth. Likewise a uniform mix is produced.

We have learned from experience that the 20 inch minimum depth of blade is necessary in order that the material will not clog in front of the moldboards. This depth allows sufficient room for proper turning and a mixing of all ordinary thicknesses of applications. The angle at which the moldboards are set has been found to result in the greatest efficiency. A steep-angled blade will result in greater capacity and a less mixing action, while a low-angled blade will result in greater mixing action and less capacity. The angle at which the moldboards in this machine are set has been found to give the greatest combined capacity and mixing action with the minimum sacrifice of one for the other. The curved moldboard is a large factor in obtaining this efficiency.



*Galion Multiple
Blade Mixer*

Another desirable feature of the multiple blade principle is the 'massaging' action given the base course. This action is a result of the slight shoving of the material in front of the moldboards. Any excess asphalt that may have deposited in a depression is thus carried into the mix. Likewise, any pockets of fine material or dust are brought up from the base, thus giving additional assurance of a bond between the surfacing course and the base.

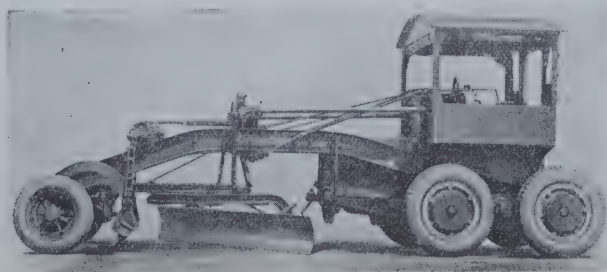
The number of mixings required is dependent on the number of applications of asphalt and the setting up or curing time of the mix. Excellent results have been obtained with one application of asphalt and one mixing operation. However, this is a matter to be determined on each particular job.

The capacity or the amount possible to be mixed in any certain time depends on conditions surrounding the particular job. As this machine can be drawn at any reasonable rate of speed its capacity is dependent on the speed at which the tractor can draw it and the amount of asphalt that can be applied. We know of several instances in which as much as two miles have been given two mixings in one ten-hour day. This machine will thoroughly mix as much as two hundred pounds of aggregate per square yard.

While this machine is intended mainly for mixing, it may also be used to advantage in shaping the aggregate on the roadway before application of asphalt and also for preparation of sub-grade or base.

We also manufacture smaller machines of similar design for use on light mulch treatments.

I will now describe a recently developed spreader box for use in placing either hot or cold plant mixed material. This machine consists of two parallel runners 12 inches high and 26 feet in length. The runners are connected at each end and in the center by a 6 inch torque tube, thus making a rigid frame structure. The spreader box proper is fastened rigidly to the forward end of this frame. An adjustable strike-off blade is located just back of the spreader box for the purpose of gauging the rate of flow or thickness of pavement. To the back of this is located two adjustable diagonal blades which serve to carry a small amount of material from one side to the other and back in order to fill any depressions and at the same time remove any high spots. The long runners prevent any irregularities of the base showing up in the surfacing course. This machine is drawn by any suitable size tractor. The hitch is effected by the use of a cable or chain fastened to each side of the machine and extending parallel to a distance of about 30 feet ahead to a spreader bar and then to the tractor hitch. The trucks back in to the rear of the tractor to the spreader box. The truck simply dumps the load into the box as the tractor draws the spreader box ahead. This arrangement eliminates any unevenness due to jerky or unsteady pull of the spreader box by the truck. Excellent results have been obtained with the use of this machine in placing a pre-mix surface for resurfacing over an old pavement.



Galion blade grader

Plant Mixing Equipment

By J. H. FLYNN
Blaw Knox Co., Pittsburgh, Pa.

You have had from Mr. Larry West, who is old in this industry, an able presentation of the case for *accurately controlled* pavement mixes made by the Plant Mix Method. He reasons cogently that we must take immediate advantage of the developments made by the *cement concrete* industry to the end that *smooth road surfaces* be produced and surfaces that *stay smooth*. We must, he notes, not fail to loyally back up in our practical construction the *asphalt chemist* and his laboratory developed specification for a mix that produces the *ultimate* in durability and satisfaction for the public (who buy and use the pavement) from the aggregate available.

The asphalt road contractor is the link between the ideal specification and the road the public gets. It occurs to me that a *clear light* might, to the advantage of all of us, be shed on the contractors' fundamental plant requirements.

Mr. West has noted the low costs for which highest grade pavement is now being laid on highway road surfaces. Enormously increased mileages of such fine asphaltic pavement will be specified by highway departments if such costs be continued. In a discussion with Mr. Gray, Highway Engineer of the Institute, I brought out the following 3 *major essentials*, as the criterion for a highway paving plant filling the bill and he asked me to present these to you:—

1. Plant capacity not less than 75 tons per hour continuously, with possibilities of increase to 100 tons when conditions of aggregates and road job itself permit.

My reasons for this requirement are based on the following ideas:—Such large capacity plant is really needed to insure reasonable profit per day within the lowered prices which prevail. Trucks must be loaded out fast and a mixing box of 3000 lbs. capacity can be considered small enough for that element of the plant.

Finishing machines in standard use will easily handle, as Mr. West notes, the surfacing of a mile of standard width road per day. So the output of the plant need no longer be constricted by any failure of the road gang to place the mix as fast as it can be delivered from the plant.

2. *Mobility of the entire mixing plant* with its boiler, liquefying tank, dryer, screed, bins, etc., is essential. Keeping in mind that 10 miles of 2" resurfacing on a 20-foot road requires only 12,500 tons of asphaltic concrete, such large capacity plants must be moved frequently. To permit the contractor to gain advantage of shortest possible hauls (and *he needs every advantage* to pull out *with a profit* or to *land the job* in the first place) his plant must be arranged so that it can be knocked down, moved over highways with standard trucks and set up again at low expense. Keeping, further, in mind the fact that only a *portion* of the yearly limit of 100 to 150 days are really available to him for pavement laying such plant moves must be completed in *very short time*. Even 5 or 6 days for the plant to be out of service for such an operation is a financial strain. Insistence on this point by the contractor will be met by manufacturers' designers, *and unless met in practical fashion, the advantage of large output per hours is lost*.

3. The plant must continuously produce bone-dry aggregates from the material economically available at a rate governed only by capacity of road gang to lay and this irrespective of weather that day or the day before. These aggregates must continuously and with unfailing accuracy be sized and weighed into the mixing box exactly in accord with the laboratory-made and engineer-controlled specifications.

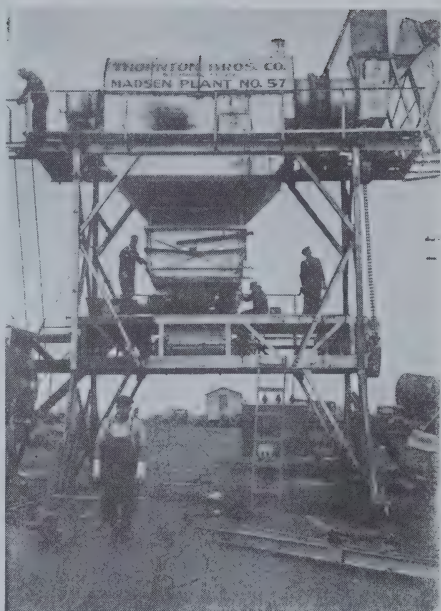
Weighing apparatus for producing this requirement is standard practice and has been fully developed for both asphalt and cement concrete plants. The demand for

some years for such equipment has been so great that apparatus of remarkable and unfailing accuracy is available at reasonable price.

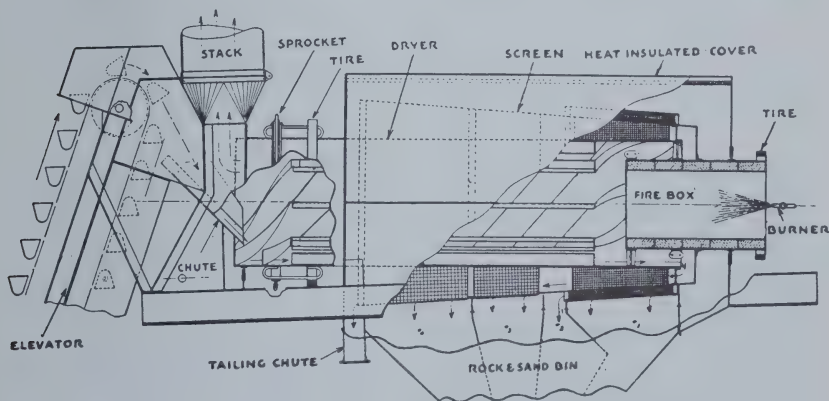
It hardly need be said that plant breakdowns due to failure of machinery parts should not be countenanced and need not as all the elements of design are old and time-tried.

Every point made by me is quite practical and such plant is available to the industry and from a sufficient number of manufacturers to give the contractor freedom in selection and purchase.

To the end that such "ideal plant" may be made available for the object in view, i.e., producing the greatest mileage of high-grade road pavement that the available funds will buy, we need, I think, cooperation of State highway departments in laying out contracts involving not less than say 25,000 tons of plant mix where possible.



Modern Plant in process of erection



DRYER-SCREEN WITH INSULATED COVER

The Patented Dryer Screen is mounted on top of the bin, fed by a "cold" elevator. The Dryer with its revolving oil-fired furnace is surrounded by a set of conical screens which revolve with the dryer—all in the "hot zone." Aggregates are screened to specified size, dried, heated to proper temperature, and delivered to bin compartments immediately below.

Asphalt Plant Design

By MARION P. WALL

Chief Engineer, The Simplicity System Co., Chattanooga, Tenn.

Accurate control is, of course, the first requisite of a plant outfit. It must carry out accurately and uniformly the design of mixture established by the chemical engineer.

Economy is to be sought in reduction of operating payroll; in fuel saving; in capacity; and in dependability and durability.

The plant manufacturer's job is to provide the civil engineer, the chemical engineer, and the contractor with equipment that will produce results in the finished mixture accurately and economically.

The detailed problems in asphalt plant design are too many to be covered in a brief paper. It is easier to show than to tell of such details and, for this purpose, we have animated drawings which will be shown later. However, for better understanding before showing these animated drawings, we will give you a brief outline of the problems as we understand them.

Portability

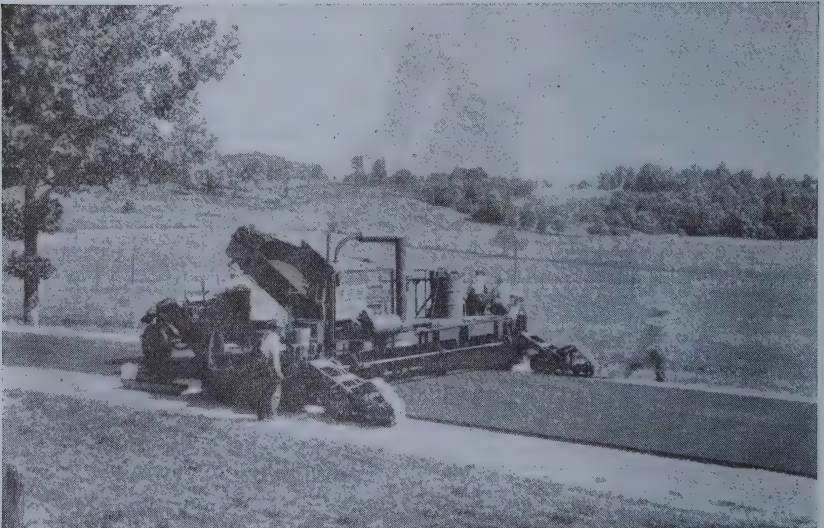
There is a question of how much you should sacrifice in sturdiness and efficiency to secure portability. We adhere to the belief that efficiency is more important than portability. However, we have gone as far on portability as we think is justifiable.

Feeding

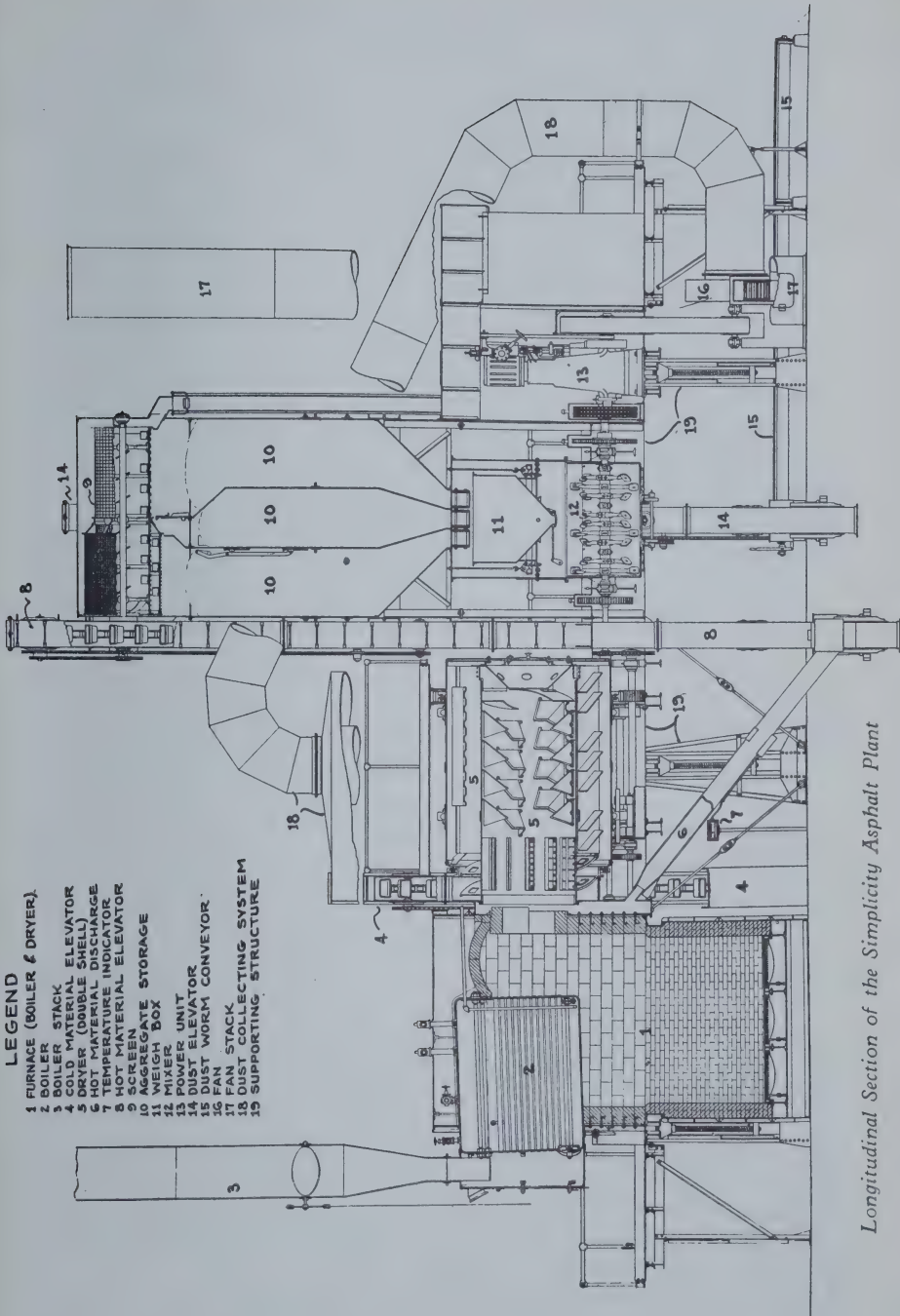
Automatic and accurate feeding is essential to temperature control and economy; also, to avoid disturbing the grading of the mineral aggregate. In our apron conveyor, or caterpillar type of feeder, we have accomplished a very satisfactory solution of this problem.

Drying

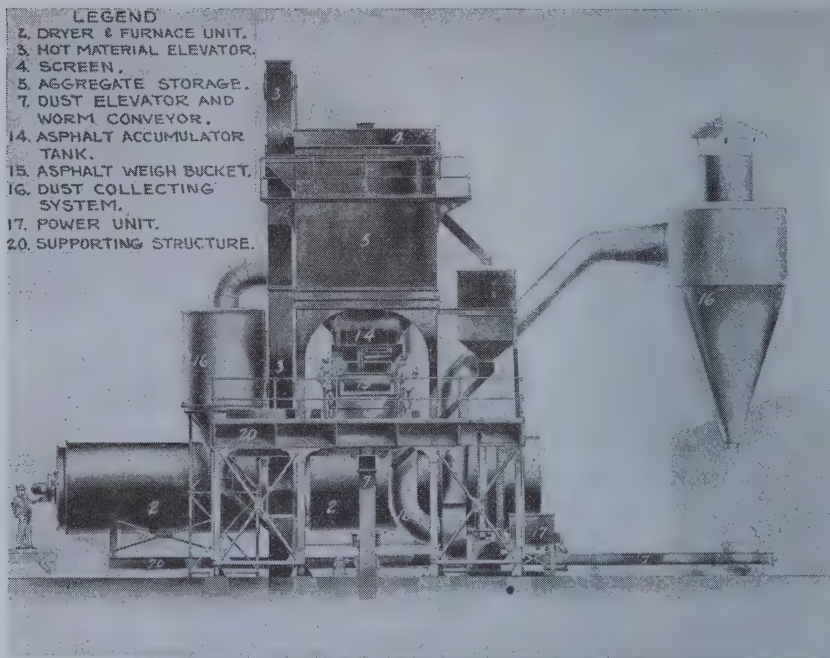
This is unquestionably the most expensive single operation in an asphalt plant and it is also the most destructive to the apparatus. It is expensive fuel; destruc-



A finishing machine operating without forms



Longitudinal Section of the Simplicity Asphalt Plant



Side elevator of Simplicity Plant setup

tive by reason of the contact of high temperature gases with the unprotected metal surfaces in the dryer. Some methods of drying also cause the loss of a large percentage of the finer particles of the mineral aggregate that escape with the flue gases.

It will later be shown in animated drawings how we have solved this problem in the Simplicity Double-Shell Dryer, which has great fuel economy and which is a solution of this problem satisfactory to many engineers and contractors.

Screening

Ample area of screening surface is a necessity to the proper, accurate grading of the mineral aggregate and, with the increasing tendency to greater plant capacities, the problem of getting a sufficiently large screen of the usual rotary type into the available space is becoming more and more difficult.

We are not satisfied with our own efforts in this direction and are about decided that, in the larger plants, it will be necessary to resort to shaking or vibrating screens to secure the sharp separation of sizes necessary to accurate control and uniformity of mixture.

Asphalt Supply

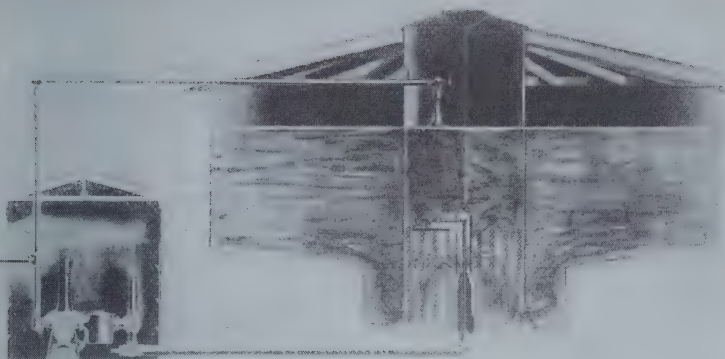
To unload and store and then heat and reclaim large quantities of asphalt cement without waste or injury to the material; to insure a uniform temperature at the weigh bucket; and do it all economically, is a proposition that we have worked out in a highly satisfactory manner with our steam storage and supply system, as shown in the animated drawings.

Filler Dust Supply

To unload, store, reclaim, and then deliver to the weigh box economically and without waste, and also avoid the dust nuisance is a problem we have solved satisfactorily as far as the average asphalt plant set-up justifies. A better method, we believe, on stationary plants, would be the Fuller-Kenyon Pump, as used by the Cement Industry, or like means, but this would be somewhat expensive in first cost and more difficult to install.

Weighing Accurately

This is a highly important problem, as all engineers and technologists realize. Assuming that the chemical engineer calls



Asphalt storage and heating tank

for four gradings of the mineral aggregate, accurately proportioned, and also filler dust and bitumen, there are required six (6) accurate and dependable weights. We accomplish this satisfactorily to the chemical engineer with either beam or dial scales, as their preference and their specifications require. The beam scales have an advantage in ruggedness and with the tell-tale attachment showing approaching weight, accurate weighing can be accomplished. Springless dial scales are also dependable and will accomplish accurate weighing. It is possible to accomplish this important function of weighing with one man but the action is more hurried where six separate operations of drawing and weighing are required, and, therefore, more susceptible of error. Complete automatic weighing is now quite practical and will probably be justified in some permanent plant set-ups in the future.

Mixing Efficiency

Confining our remarks to the pug mill type of mixing exclusively, the essential features of this important function in an asphalt plant are:

(A) To dump from the weigh box into the middle of the mixer and cross-wise to the shafts so as not to give one end of the mixer stone and the other end sand.

(B) To time the batch dry; that is, before the asphalt is added, and then time the batch after the asphalt is added, both timings being under locked control.

(C) Thorough circulation within the mixer, so that the batch, when completed, will be found uniform throughout when tested for bitumen content and grading.

(D) Quick adjustments of mixer paddles so as to facilitate the maintenance of proper clearance with the mixer bottom.

(E) Quick dumping and thorough cleaning, and the maintenance of the mixer at a uniform temperature by steam jacketing, are essential features.

(F) Complete housing of the mixer to prevent the escape of the filler dust and the finer particles of the mineral aggregate during the process of dry mixing. Such housing is also an advantage in avoiding the dust nuisance on the platform.

Temperature Control

Uniform automatic feeding to give a constant, uniform load in the dryer shell will, in combination with a uniform fire, insure steady and easily controlled temperature of mineral aggregate.

In the asphalt supply system, a steam heated storage tank of considerable capacity and the use of a steam heated accumulator-tank at the mixer will automatically hold the asphalt at a uniform temperature.

We have found that it is an advantage to utilize a compartment of the hot aggregate bin for filler dust, so that the dust receives some warming before it is drawn into the weigh box.

Cold Mixes

This refers to all cold mixes produced by drying and then cooling the mineral aggregate, whether the bitumen content is a cut-back asphalt or a blending of hard oxidized asphalt and liquid asphalt. These can be handled satisfactorily in our hot mix plant, as will be shown by the animated drawings. You will note that we first dry the aggregate in the outer shell of the dryer and then cool it in the inner shell. The animated drawings show that adjustments are provided in the weighing apparatus to take care of the different types of cold mix.

Dependability

We have considered many improvements in the design of asphalt plants. Most of these have been rejected because they could not be made dependable. Dependability at all times—the ability to turn out a complete mixture, in which the engineer

can have complete confidence—is, we consider, the first requisite of an asphalt plant.

Moreover, the plant must be dependable so that the contractor may work without interruption and so that he may know what his production and costs will be.

Mechanical ruggedness and dependability are necessities, because the extreme hard service to which the average asphalt plant is put causes rapid depreciation. Many attractive designs and theories have been advanced for designs in asphalt plants but hard knocks have taught us to question them. Dependability under long, hard service cannot be sacrificed, nor can any question be raised as to the control and dependability of the mixture that is to be turned out. Plants with large capacities are called upon to produce several thousand dollars worth of completed work in a single day. Any errors in control are detrimental to the road, and delays are expensive to the contractor.

Asphalt Plants

By RALPH C. HEATH

Mgr., Iroquois Dept., The Barber Asphalt Co.

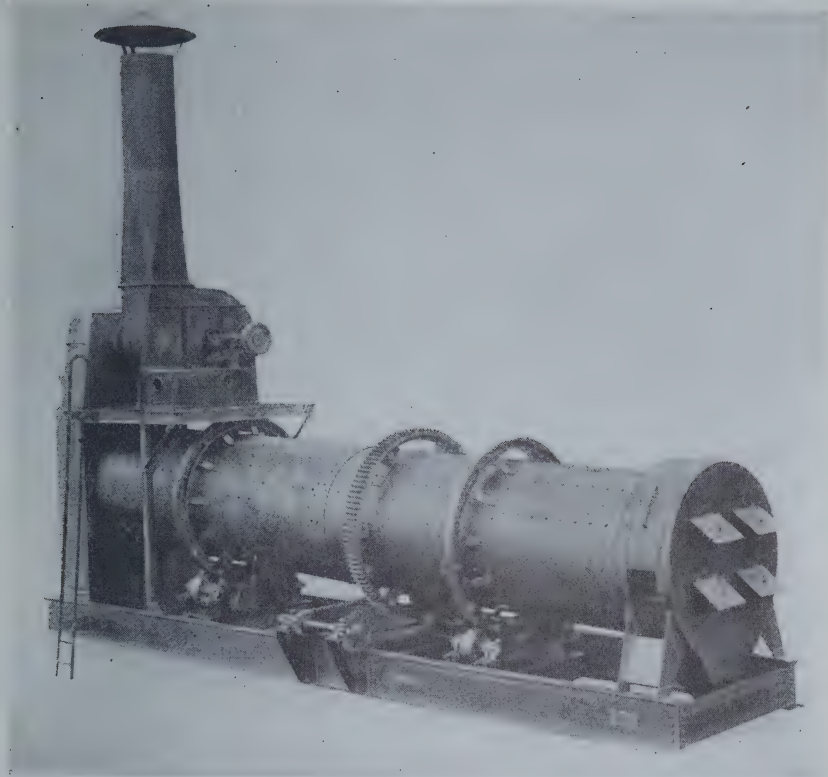
1.—Pre-Mix Gravel Plant

Briefly, this plant consists of two units, the dryer unit and the mixing unit.

The dryer is of the open internally fired type of our monopole design carried on trunnions mounted on a structural steel frame which in turn is mounted on wheels, thus making it portable on its own wheels and permitting it to be trailed by a tractor or by other means, or loaded on a railroad flat car for transporting long distances. This dryer is 60" in diameter by 20' long and is capable of drying approximately 90 tons of aggregate per hour having a moisture content of 3 per cent. At one end of the drum a steel encased combustion chamber or furnace is provided in which complete combustion of the fuel oil from the oil burners takes place before passing through the mineral aggregate in the dryer drum. At the opposite end of the drum, at which end the

cold material or mineral aggregate enters, there is provided a structural steel and plate casing. A 70" exhauster is provided having a capacity of 15,000 cubic feet per minute and is used for removing the hot gases from the dryer. The drum is set on the frame at a pitch of $\frac{3}{4}$ " per foot. The burners are capable of burning 240 gallons of oil per hour. A gasoline engine for driving the dryer drum and cold material elevator is provided and mounted on the dryer frame adjacent to the cold material end. The exhauster is driven by a separate engine mounted on a special frame and can be located adjacent to the dryer. This engine can also be utilized in raising the mixing platform into position in assembling the plant.

The mixing unit consists in general of the mixing platform, a 40 cu. ft. twin shaft pug mill mixer, a scale and weigh-box for mineral aggregate, a scale and



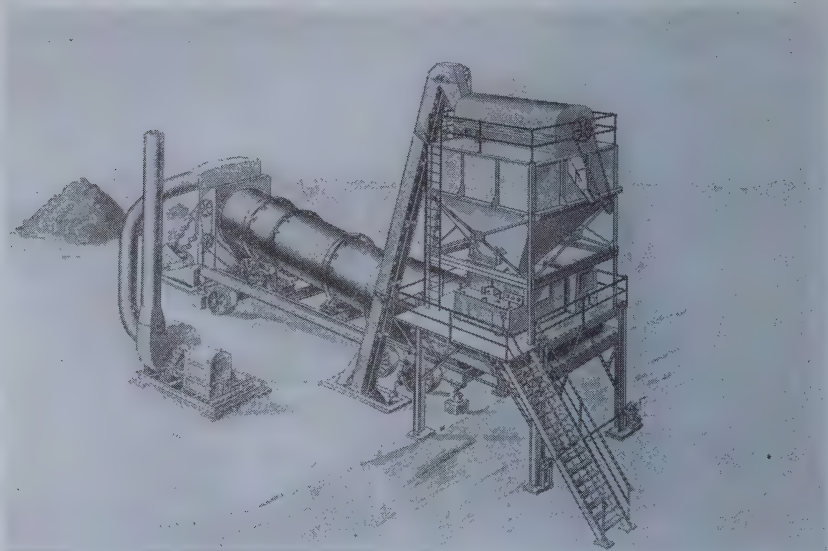
Iroquois cold type dryer

weighbucket for asphalt, an asphalt pump, the required steam jacketed asphalt piping and fittings, as well as a gasoline engine power plant for driving the hot material elevator, mixer and asphalt pump. Bins are provided over the mixing platform for the storage of dried material which is conducted from the dryer by means of the hot material elevator. A totally enclosed revolving screen is located over the bins so that the aggregate can be graded at this point and separated into two or more gradings and fed into the compartments in the storage bin. The top of the mixer is located below the level of the platform floor. This permits all operating levers to be in the most accessible position for easy operation. The weighbox, asphalt bucket and mixer are all totally enclosed and all operating levers and scales are located on the outside in easy reach of one operator. An improved patent-applied-for weighbox is mounted

on a suspended type hopper scale and a new patent-applied-for design of steam jacketed asphalt bucket suspended on a two-beam scale with tell-tale dial is furnished. Automatic time locks for the mixer discharge, asphalt bucket valve and weighbox can be furnished. The mixer is of the pug mill type featuring a double slide and resulting in a larger opening which permits quicker discharge of material from the mixer. The entire mixing platform can be raised or lowered by special means, facilitating easy assembly. The mixing platform when set up for operation is high enough to permit trucks to drive there under and into which the mix from the mixer is dumped.

The rated capacity of this plant is 100 tons per hour.

In addition to the two units described above, it will be necessary for a steam boiler to be provided as well as storage for asphalt. We are in a position to fur-



General view of Iroquois pre-mix gravel plant

nish these additional units or they can be procured locally by the customer.

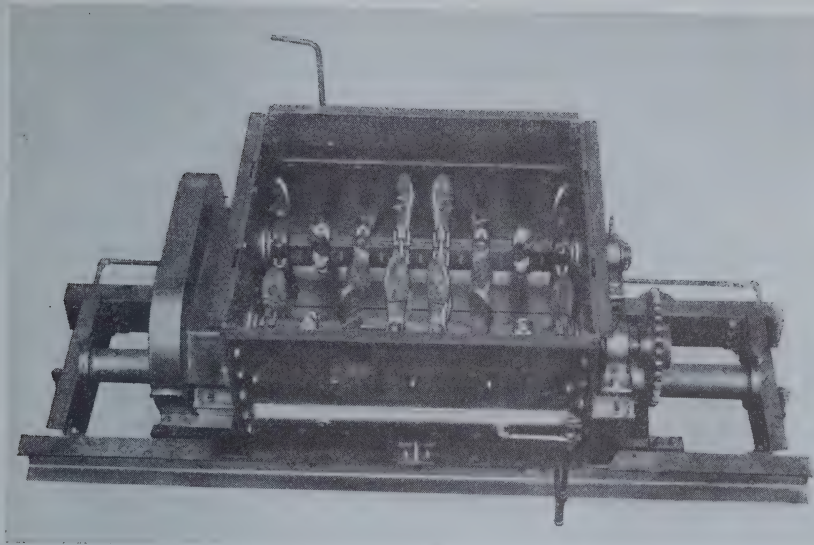
2.—Cold Mix Plant

The cold mix plant also consists primarily of two units, the drying unit and the mixing unit.

The dryer can be furnished in two sizes, namely, 66" in diameter by 30' long, having a capacity of 20 to 30 tons per hour, or 78" in diameter by 30' long, having a capacity from 30 to 50 tons per hour. This dryer is capable of drying the required quantity of mineral aggregate and at the same time cooling it to atmospheric temperature in the same drum. It consists of the conventional drum mounted on trunnion rings running on trunnion rollers and driven by a large ring gear attached to the drum; cold material end housing and dried material end housing. At one end of the drum a cylindrical combustion chamber is located within the drum attached to and revolving with it. No material passes through this combustion chamber but passes around it and is consequently dried not only by the hot gases but also by the material coming in contact with the hot surfaces of the combustion chamber. A special alloy steel baffle is located at the end of the combustion chamber which deflects the hot

gases so that counterflow of gases and material is afforded. The amount of cold air entering into the dryer is controlled by six dampers, five of which are on the cold material end. An exhauster is provided and mounted on a steel framing over the cold material end of the dryer. The dryer is fired by an oil burner attached to the cold material end housing. This burner is equipped with special controls for primary and secondary air entering the combustion chamber. The dryer can be driven either by means of an electric motor or a gasoline engine.

The mixing end consists of a mixing platform on which is located a 2-ton twin shaft pug mill asphalt mixer, a scale and weighbox for mineral aggregate and a scale and weighbucket for asphalt. The weighbox is an improved patent-applied-for weighbox mounted on a suspended type hopper scale with a metal beam box. Liquefier equipment consisting of liquefier unloading hose, liquefier measuring equipment consisting of nozzles, relief valve, meter and necessary piping are also provided. Over the mixing platform a storage bin is furnished capable of holding over an hour's supply of dried material. A bucket elevator is provided for handling the dried material from the dryer to the storage bin. A revolving type screen is



Interior view Iroquois type pug mill mixer

located over the storage bin for properly grading the aggregate and delivering the same into the compartments in the bottom. The entire mixing end is carried by a structural steel tower which can be set on concrete foundations.

Additional equipment consisting of steam boiler and storage tanks can be furnished or can be supplied by the customer. The capacity of this plant is dependent upon the size of dryer.

Special Features on New Iroquois Portable Asphalt Plant [Daily capacity 1000-1500 square yards]

The cold material elevator is equipped with 8 by 5 buckets with reinforced lip and malleable back for extra-heavy service. These buckets are mounted on C-131 chain with combination steel side bar and malleable attachment link on heat-treated alloy steel pins. The capacity of this elevator is liberal, being 20 tons per hour if the buckets are all filled to 75 per cent of their capacity. The chain runs on flint rim sprockets. The head shaft is mounted on dust proof self-aligning roller bearings. The boot shaft is filled with babbit bearings mounted on an adjustable takeup. The takeup is mounted on a steel channel frame anchored to a concrete hopper type foundation. This type of cold

material elevator can be had in either single end feed, side feed for either side, as well as double side feed for sand or stone on one side and stone on the other, if desired. Each of these can be operated independently of the other or in combination.

At the present time the plant is to be equipped with a 30" exhaustor with adjustable control, the fan shaft running in water cooled bearings and being driven through endless V type belts running in grooved sheaves. The belts may be easily removed and replaced if required. Partial dust separation is obtained at the feed end of the plant by the construction of the feed end housing.

The feed chute to the drum is made of heavy gauge steel plate equipped with wearing plates at the bottom. An open type drum constructed of $\frac{3}{8}$ " thick plate made of firebox steel with a welded joint makes up the shell of the dryer. On this drum is mounted seamless steel tire trunnions. Trunnion rollers of cast steel mounted on heavy cold rolled steel shafts mounted on heavy duty self-aligning roller bearings with dust tight case are furnished. Roller chain drives are furnished on the main line shaft to the mixer jack shaft and also to the speed increaser driving the exhaustor. The fur-

nace for this dryer is of the high turbulence type with a tangential inlet having ample combustion volume and radiation area and is suitable for burning fuel oil of 16 Baume gravity or lighter. The burner is of the high pressure steam atomizing type. Primary and secondary adjustable air inlets are provided and additional secondary air inlets are provided permitting entrance of air between the steel housing and the brick lining of the furnace which serves the double purpose of keeping the brick cool and at the same time pre-heating the air, thereby resulting in higher combustion efficiency.

The hot material elevator is equipped with the same type of buckets and chain as on the cold material elevator. The head shaft and boot shaft sprockets are of the flint rim type mounted on dust proof self-aligning roller bearings. The case is made of heavy gauge steel of welded construction. This elevator is equipped with automatic boot takeup roller bearings having a patent-applied-for counter-weighted toggle type adjustment which will readily take care of expansion and contraction in the chain as well as wear in the same. The chute from the hot material elevator to the screen is made of heavy gauge steel and equipped with steel liners. The screen is of the rotary type and is easily replaced. It is equipped with a dust tight screen hood over the entire screen, which hood is hinged at one side and is easily removed, thereby affording both inspection and easy access to the screen. The entrance end is entirely open, not being obstructed by a spider and is mounted on a trunnion ring and rollers. The slope of the screen is adjustable and can be regulated as conditions require. The working capacity of the hot material bin is 10 tons or slightly better than an hour's supply in storage.

The hopper is made of heavy gauge steel of welded construction so that it is tight and no leakage should occur from the same. Improved type gates have been incorporated in the bottom of this hopper. An improved patent - applied - for weighbox mounted on a suspended type hopper scale with a metal beam box within easy reach of the operator has been installed, the screen being furnished with a tell-tale dial.

The standard plant will be equipped

with the new style No. 750 pug mill mixer and if additional capacity is required, sufficient space has been allowed for the installation of a new style $\frac{1}{2}$ -ton mixer. We have already given you specifications and an outline of the features covering this new mixer and briefly wish to outline the most important of the same.

The mixer is equipped with self-aligning and dust proof roller bearings. The mixer shafts are forged nickel chrome heat treated steel. Special alloy steel blades are furnished with manganese steel tips. Manganese steel shell liners and slide liners with special steel end plate liners are provided. A liquid seal is secured at both ends of the shafts and the mixer is equipped with a welded and staybolted high pressure steam jacket. The mixer is also equipped with a double slide resulting in a larger opening, thereby permitting quicker discharge of material from the mixer. Cut tooth gears are provided and the mixer is driven through a jack shaft gear and roller chain.

A new designed patent - applied - for steam jacketed asphalt bucket suspended on a 2-beam scale with tell-tale dial is furnished. This asphalt bucket is equipped with a valve arrangement which sprays the asphalt into the mixer and the valve is so designed that leakage is prevented and it is self-cleaning in its operation. Mineral filler is fed into the weighbox by means of a clutch operated screw conveyor driven by chain drive from sprocket on the intermediate shaft. This conveyor can either be charged by hand as in the case of the standard plant or a separate mineral filler elevator can be installed. The weighbox, asphalt bucket and mixer are all totally enclosed, all operating levers and scales being on the outside and in easy reach of one operator. A special spring type valve for filling the asphalt bucket is provided.

The mixer discharge, asphalt bucket valve, and weighbox discharge are automatically locked and controlled by solenoid operated limit switches. These locks are so arranged that it is necessary for the operator to charge and discharge the mixer weighbox and asphalt bucket in proper sequence. When the mixer is closed, it is automatically locked. The weighbox has previously been filled and the material in the same weighed. During this operation

the weighbox is locked. When the signal light for the weighbox is lighted, the operator dumps the weighbox and the aggregate into the mixer for a certain time interval before the lock on the asphalt bucket is released, permitting the asphalt to be discharged. When the lock is released the light is lighted and the operator then discharges the asphalt bucket into the mixer. After a pre-determined mixing time, the lock on the mixer is released, the light lighted and the mixer can then be discharged. During the mixing period the weighbox and asphalt bucket are both filled and the material in the same weighed. These three lights are mounted on a panel directly in front of the operator.

The top of the mixer is located below the level of the platform floor. This permits all operating levers to be in the most accessible position for easy operation. The mixer is so placed that it can easily be dropped down, thereby facilitating repairs. The mixer platform as well as all platforms is constructed of non-skid steel floor plate. The plant can be secured for mounting on columns or concrete piers and while the running gear is not standard it can be readily furnished at a slight extra. The plant is arranged for being driven by a steam engine, gasoline engine or electric motor. If desired, an all-electric individual motor drive plant can be had, that is, separate motors for the dryer drum, mixer and elevator and screen, making three separate motors with remote control, push and button type.

A dust collector is not considered as standard equipment but can be furnished as an extra.

Iroquois Rapid Mixer

The Iroquois Rapid Mixer has been developed to meet the increasing demand for a small and inexpensive plant for the production of bituminous paving mixtures. This can be used for either cut-back or emulsified asphalt cold mixes, but its primary use is for producing a hot mix in the following manner:

The sand and filler in proper proportions are dumped into the skip hoist which is raised by power, dumping these materials into the mixer. The proper amount of a special liquid asphalt then is

added together with two pints of gasoline. The mixture is ignited and when the gasoline has been entirely consumed, which usually takes approximately six minutes, the mixture is ready to dump and is discharged out of the hand opening gate in the side of the mixer into a wheelbarrow placed alongside. This mixer is capable of producing 4 cu. ft. of mix in six minutes. The temperature of the mixture will be between 250° F. and 350° F., depending upon the weather. This mixer can be quite economical on small production. The plant is 15' 3" long, 4' 7" wide and weighs approximately 2½ tons.

The mixer is equipped with one steel shaft provided with special mixer blades having cast steel shanks with removable and adjustable cast steel tips. The tips are of such shape that the asphalt mixture will not only be thrown back and forth from one end of the mixer to the other but is lifted, cut and mixed in such a manner as to permit free access of air, thereby promoting rapid burning of the gasoline or light solvent oil used.

The mixer body is constructed of heavy steel plate and provided with removable steel plate liners on the sides, bottom, door and ends. The mixer is enclosed by a sheet metal jacket into which the hot exhaust gases from the engine are delivered. A steel wire netting is provided which prevents the flames from burning the operator.

The mixer is driven by a heavy duty horizontal single cylinder hopper cooled engine which is started with gasoline but which operates on kerosene. The engine is provided with a clutch and the mixer shaft is driven through reducing gears between the engine and the mixer. A clutch drum provided with a friction clutch and brake is furnished for raising and lowering the skip.

Specifications for Iroquois 40 cu. ft. Asphalt Mixer

The Iroquois 40 cu. ft. mixer is of the pug mill type, fitted with two shafts carrying mixer blades for mixing either topping or mixes containing coarse aggregate.

The shafts are fitted with twin gears and rotate in opposite directions, turning down at the sides and up at the middle of the mixer. The blades are made right



A Portable asphalt plant picking up untreated aggregate from windrow (A), and depositing finished mixture in windrow (B) (For cold laid mixes)

and left hand, so that they force material from one end of the mixer to the other and back again, in what is termed an around-the-box mix. The whole effect of the rotation of these blades in a mix of stone or sand and asphalt is to so thoroughly knead and toss the material that the best possible mixture of the ingredients is made in the shortest possible time.

The mixer body is 72 $\frac{1}{4}$ " inside length, 65" inside width and 39" inside depth. The end castings are made of cast iron and these castings are fitted with feet for supporting the mixer. The shell plates are made of $\frac{1}{2}$ " sheet steel and they are riveted to the end castings. Each of the shell plates is reinforced along the upper edge by a 3" x 3" x $\frac{1}{2}$ " structural steel angle and is fitted with a welded and stay-bolted steel steam jacket, $\frac{5}{16}$ " thick, into which steam may be turned to keep the mixer hot, thus preventing any sticking of material to the sides while it is in operation, and also making it possible to loosen the blades easily should they become stuck when the mixer is shut down.

The mixer body is fitted with removable manganese steel side liners, which can be replaced as they are worn by the continued grinding of sand or stone mixtures.

The mixed material is discharged through a large opening in the bottom of the mixer which is closed by two heavy cast iron slides which form the entire mixer bottom and which are carried on twelve steel slide rollers. The mixer slides are operated by means of two steam cylinders. The slides are also fitted with removable manganese steel liners and are so arranged as to prevent leakage where butted together.

The mixer shafts are 4 $\frac{1}{2}$ " square at the point where the blades are attached. These shafts are turned down at both ends to $\frac{4}{16}$ " diameter and each is carried in two rigid pillow blocks supported by 6"—No. 15.3 ship channels and 8" cast steel H section fillers. Cast iron gap plates and cast iron cheek plates are fitted in the end castings so that the shafts can be easily removed and leakage of material prevented. The shafts are extended at one end of the mixer and fitted with cast semi-steel, cut-tooth, twin gears, 28" pitch diameter with 42 teeth. One of the mixer shafts is extended at its opposite end to take either a main drive gear or can be directly connected to a motor through flexible couplings and herringbone speed reducer.

When standing in the operator's posi-

tion facing the mixer, the standard setting of the mixer is with the twin gears on the left hand end of the shafts and the drive gear on the right hand end of the furthest shaft. The power dump is operated by means of a 4-way cock placed in convenient reach of the mixer operator.

The mixer has a nominal rating of 40 cu. ft. but will handle batches up to 5000 lbs. weight, as the level full capacity is actually 97 cu. ft.

The mixer shafts can be fitted with two standard types of blades, one for top, and a universal blade which will mix either binder or top without change.

The topping blades are practically square ended and are fitted closely together on the shafts. A set of topping blades consists of 8 right hand and 40 left hand shanks.

The universal blade is somewhat pointed and not as square as the topping blade. The shape is such that it will handle mixes containing coarse aggregate as well as top and make an absolutely first class mixture. When the universal blade is used there are 8 right hand and 28 left hand blades in the mixer.

Cast iron split spacers are required between the various types of shanks to hold them in proper position on the shafts. The shanks themselves are fitted in pairs on either the flats or the corners of the shafts and are held in position by two 1" machine bolts.

All of the blades are supplied as combination blades, that is, the shanks made of cast steel, fitted with removable manganese steel tips, of either topping or universal shapes. These tips are secured to the shanks by means of three $\frac{5}{8}$ " x $2\frac{3}{8}$ " countersunkhead machine screws with nuts. This construction makes it possible to remove the tips as they become worn and install new tips without removing the shanks from the mixer and thus constitutes very decided saving in material and labor in the course of the season's operations.

The length of the shanks along the shaft is $3\frac{1}{2}$ ". The blades are set at an angle of 45° with the center line of the shaft and, as stated, are made both right and left hand.

The combination universal blade extends $17\frac{1}{8}$ " from the center line of the mixer shaft and gives a clearance of from 1" to $1\frac{1}{8}$ " between its point and the liner.

The combination topping blade extends $17\frac{5}{8}$ " from the center line of the shaft and gives a clearance of $\frac{1}{2}$ " to $\frac{3}{8}$ " from the tip to the liner.

The width of the manganese steel tips at the widest point is $5\frac{5}{8}$ " for the universal tip and for the topping tip is 6" maximum width at the outer end next to the mixer shell.

Mechanical Finishers as Applied to Asphaltic Construction

By ORVILLE H. Kiest
Blaw Knox Co., Pittsburgh, Pa.

In regard to the design of the finishing machines used today, there has been quite a radical departure from the standard finisher as used several years ago. This departure has been brought about by the desire to adapt mechanical means to a varied type of asphaltic construction. The machines are adapted to the range from inexpensive oil mix type pavement to the higher class type of work that is now termed "reconstruction."

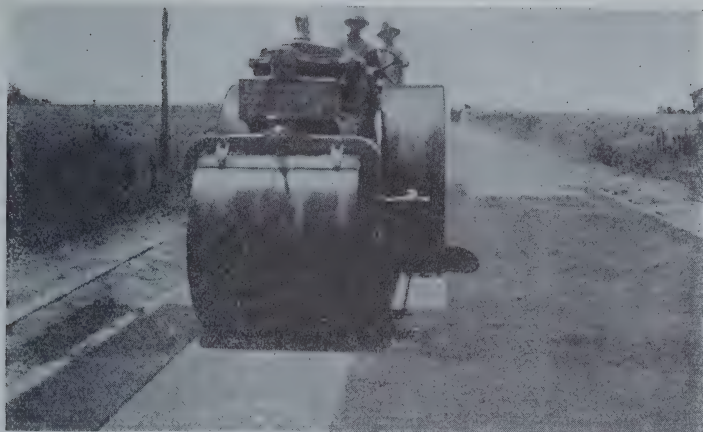
It is on this type of reconstruction and new construction that the standard concrete finisher was applied originally and where it still predominates. The finishers as originally used were identical with those on concrete construction. They consisted of a power-driven chassis running on rails, or curbs, with their operating member (termed a screed) placing the asphaltic materials to the desired crown and grade as determined by the level of the rail or curb on which the unit was operating. There has been considerable improvement made which can be attributed mainly to the asphaltic construction.

On the Ord Finisher as applied to asphaltic construction, it was quickly recognized that the amount of traction necessary to propel and operate the unit on concrete construction was not sufficient for asphaltic construction due to the fact that all asphaltic mixes carry a considerable amount of asphaltic oils. These asphaltic oils find their way to the top of the rail, or curb, and cause a considerable slippage in the drive unit, which means a considerable reduction in the capacity of the machine. To overcome this, asphaltic units are now supplied with six-wheel drives instead of four. This six-wheel drive naturally reduces the factor of slippage considerably, but does not always entirely overcome it; therefore, a positive cable and winch arrangement was designed whereby the finisher unit was propelled

forward by winch and cable, entirely eliminating slippage to traction. This assured maximum production, and where large plant tonnage is available it is very necessary to get at all times maximum finisher capacity—especially so when surfaces laid are extremely thin and a large square yardage is to be covered per day.

Such accessories as rakes and strike-off members have been formerly discussed before this body. As to rakes, there is some debate on what type of material it is necessary to apply them. In California a particular type of rake is used on asphaltic concrete and considered a very necessary item. In sections where a natural rock asphalt is laid, rakes are necessary to break up the hard lumpy consistency of the material before it will properly work under the screed of the finisher. On sheet, various types of rakes have been tried with varying success; in some instances it was evident that the rakes were helpful and in others no benefit could be observed from raking.

For the field of reconstruction, which is now widely underway throughout the State of Ohio, we were forced to design strike-off plates to allow the placing of the wedge course, or leveling course, quickly and efficiently with the finishing machine. This required compensating strike-off plates that would ride up over high spots in the old surfaces, and then drop down again to their normal position. It had been the general practice in this type of construction to use some type of riser strip to lay the top course, but due to the inconvenience of moving these riser strip units ahead of the finisher *continually*, a means was devised whereby a rolling riser plate could be fitted to the machine itself, giving the desired thickness of excess for compaction and eliminating the expense of continually moving the separate riser strips ahead.



Mechanically spread asphalt mix in Georgia

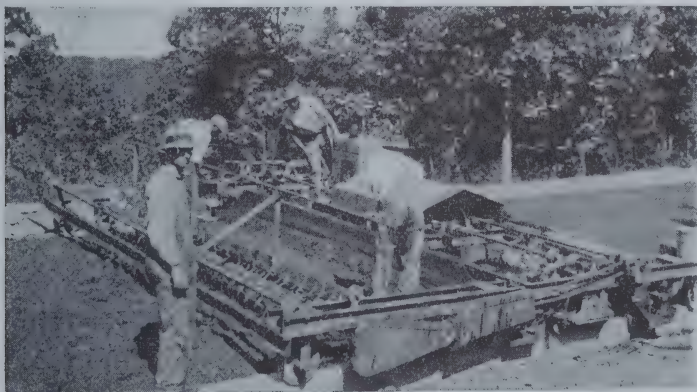
Another item that was developed and brought to the front due to the reconstruction method, as used throughout several states, was the development of a type of drive wheel that would not injure the curb on which it was operating. This eliminated any necessity of protecting the concrete curb, while operating on it with a finishing machine.

All the above mentioned items are new to the industry and yet all of them are applied to the basic mechanical concrete finisher when it is put to work on asphaltic construction.

When the standard finisher is thus used on asphaltic construction and the necessary accessories applied thereto, the resulting

pavement is in every way as smooth as the cement concrete surfaces.

Recognizing the tremendous strides that have been made in the last few years in the application of mechanical finishing as applied to asphaltic construction on streets and roads, there is still a vast amount of work yet to be done—especially so in coordinating this type of equipment with other equipment necessary to complete the operation required to secure the finished product. Some of these improvements are being perfected at this time. For example, the coordination of the rolling with the finisher, especially in regard to the initial rolling, as it is very much desired that as much compaction as possible be se-



Ord Finisher showing revolving rake



Mechanical finishing on cold laid asphalt in Ohio

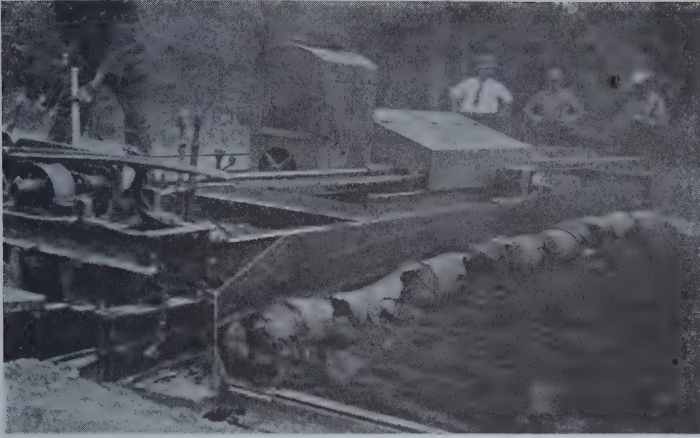
cured before a standard roller is applied to the surface. This compaction should be performed on the material as it is being laid or placed by the finishing machine equipment. To secure equal distribution of materials as they feed from the truck before being worked with the finishing unit is another desired improvement. Such equipment in several instances is in the stage of early development, but is sure to develop into a finished product and when so developed, will further increase the efficiency of the machines used on the street.

Heretofore, with hand methods the capacity or daily production was governed by the efficiency and the size of the street or road crew. With the finishing machine, with its unlimited capacity (governed only by its established working speed) the street restrictions were removed and the tonnage per day capacity was based on the size, type and efficiency of the mixing plant. Under hand methods, 300 to 400 tons per day was considered extremely large production; under mechanical methods, this production was advanced to 1500 tons per day with very little increase in labor units on the street, but, with a very decided decrease in cost per ton for laying. This decrease in cost per ton for laying was accomplished by the doubling and tripling of the daily tonnage without any additional street cost over the cost per ton under a 300 and 400 ton capacity day.

Further economy was also secured at

the plant end of the work as it did not cost any more to mix a 4000 lb. batch than it did to mix a 1500 lb. batch, therefore plant capacity was stepped up by increasing the size of the mixer boxes with the proportional increase in dryer capacity.

In connection with this another step has been taken which will be very readily recognized as increasing the capacity and economy and coordinating with the finishing unit on the road: namely, the portability of plant construction. This matter of portability is very noticeably brought to the attention of the industry by several plant manufacturers who are producing portable plants with capacities ranging up to 150 tons per hour. This portability is not in name only, but these plants are actually portable, inasmuch as they can be knocked down, transported over the regular high ways, and set up within a period of 3 to 4 days when desired, or easily in a period not to exceed a week. This combination of large output with plant portability with finishing machines used on the street or highway opens up the field of reconstruction to the contractor where a small total tonnage per mile is called for and the plant must be moved to another set very shortly. It also gives to the asphalt industry a flexibility in equipment equal to the flexibility secured by the cement concrete paving contractor of the present-day placing the asphalt industry on an equal footing in the paving construction field.



Finishing sheet asphalt in Michigan

There has been another somewhat similar type of finisher designed, but incorporating its own spreader box. This machine has the facility of being able to operate on most any type of material, but due to the fact that it also operates directly on the surface or sub-base without any rail or curb to guide it, the resulting

pavement is not as high class as produced with the standard finisher operating under standard methods.

Surveying all the asphaltic work constructed during the past year on which mechanical means of spreading and laying have been applied the standard machine riding on forms still predominates.

The Use of Mechanical Finishers on Asphaltic Concrete

By LION GARDINER

President, The Lakewood Engineering Company, Columbus, Ohio

In support of one of the comments in Mr. Gray's paper as to the importance of mechanical finishing equipment on bituminous pavement, it might be of interest to review the important features of the longest resurfacing job let in the State of Ohio, which was completed on December first, this year.

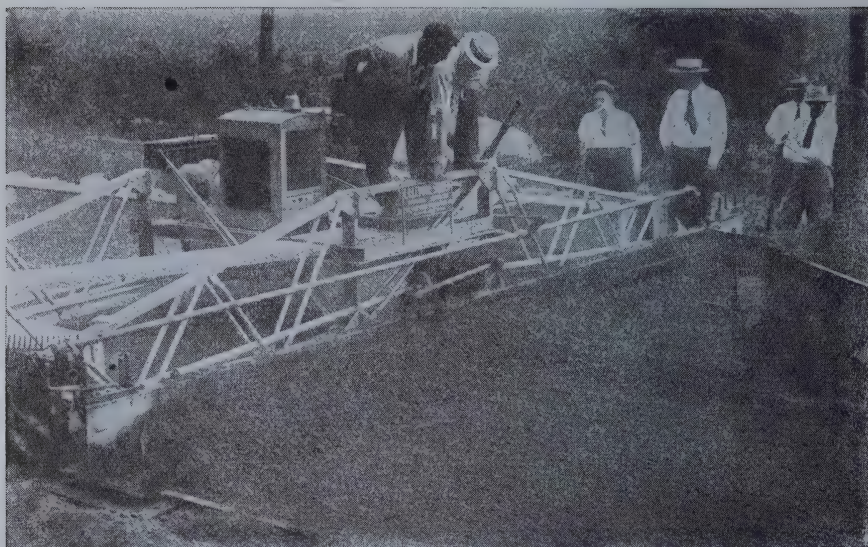
On U. S. Road 30-S, the Lincoln Highway, East from Lima, Ohio, the Wesco Company, of Chattanooga, M. Russ, General Superintendent in charge, has just completed the resurfacing of an old macadam road, installing 2 ft. of concrete widening on each side, the outer 9" of which carried a header to act as a curb, between which was built an asphaltic concrete surface, 18' 6" wide to the T-5 Ohio hot plant mix specification, the road being 20 ft. over-all in width.

The construction necessitated the laying

of a wedge course to correct for the old crown which was excessive, then a base or binder course approximately 1½" thick and a 1" top course.

The job was 24¾ miles in length, requiring approximately 40,000 tons of material and built from a single plant set up in Lima, with a maximum haul of approximately 26 miles, the material being handled in 5 to 6 ton capacity trucks.

The work of laying black top was started August 25th and completed December 1st, the operation being carried on in two eight-hour shifts working six days a week, except toward the end of the job when cold weather set in, when the seven day week was used. Due to bad weather conditions, rain and snow, four to six weeks of working time were lost, there being prior to the middle of November a nine-inch fall of snow, materially delay-



Finishing Asphaltic Concrete with the Lakewood Machine

ing the work which, according to original planning, would have been completed prior to November first.

A West Simplicity Asphalt Plant was used with a 2250 lb. mixing box and the maximum tonnage laid in two eight-hour shifts was 940 tons. While working under normal conditions without weather disturbance, the production approached two miles of finished road every three days and the maximum individual run was one mile of 1" top in twelve hours.

A Lakewood Finishing Machine with special inside flanged wheels riding the concrete headers, and a new device known as a "compression strip dolly" which eliminates the necessity of carrying forward compression strips, was used throughout the work and spread not only the top and base course, but the wedge course as well. It was equipped with special high speed gears giving a forward speed of 14 ft. per minute, specifications allowing for 14 ft per minute on wedge course and base course and 10 ft. per minute on top.

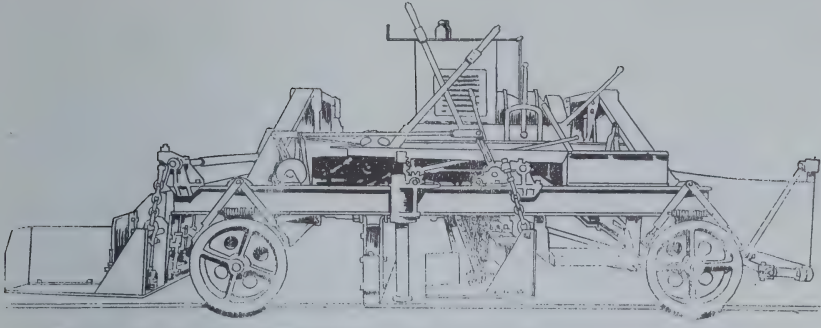
In conjunction with the finishing machine, there were two spreader boxes for rough spreading the material and into which the trucks dumped. The labor gang consisted of four men in front of the finishers operating the spreader boxes and assisting in spreading, one finisher opera-

tor, two back rakers and three 10 ton rollers.

In connection with the results obtained through the use of the Lakewood Finishing Machine, in combination with good roller operation, two important features stand out: first, that a crew of four men in front and two behind spread and finished, ready for the rollers, a maximum of 11,500 square yards of top in 12 hours; second, that on the first 8½ miles of work which had been checked and accepted by the engineer, there were but seven bumps in excess of ¼" in 10 ft. Since cold weather set in, it is anticipated that there would be an increase in such inequalities but due only to the extremely bad weather conditions.

The T-5 specification is the new type of non-skid hot mix surface first tried out by Ohio in 1931 and is proving very satisfactory.

As to the application of finishing machines to bituminous surfacing, there has yet to be presented to the Lakewood Engineering Company a problem in finishing various materials with the exception of the extremely stiff cold mixes, which could not be satisfactorily handled with a finishing machine either in one or two lane construction. This past year has seen further mechanical refinements in the ma-



Drawing showing side elevation of Lakewood Finisher

chines for their adaptation to bituminous surfaces and of importance is the improvement as to an attachment avoiding the necessity of carrying forward compression strips. This attachment being very easily attached to the standard finishing machine.

Standard sizes have been operated on roads 9 to 30 ft. in width and where wider roads have been encountered, a successful two lane method of operation has been inaugurated.

It is the belief of this Company that the added smoothness and reduction in cost through the use of finishing machines will make worthwhile the use of steel forms on some of the lower type of roads where construction cost has been the first consideration.

Aside from the foregoing operating improvement, there is also an advantage

due to the fact that with the stripping of the forms, the side of the road is found compressed and in a vertical plane so that when the earth shoulder is moved against it and again rolled, there is considerably less liability of raveling at the edge, thus reducing materially further maintenance cost. This viewpoint, we believe, is becoming more general with engineers and the slight additional cost for the use of forms amounting to perhaps a cent and a half or two cents a square yard is well worth the original investment considering the possibility of future savings in maintenance plus a smoother riding road from the start.

This particular thought as to the use of road forms is especially suggested for the general consideration of those in charge of this type of design.

Mechanical Spreaders for Asphalt Mixtures

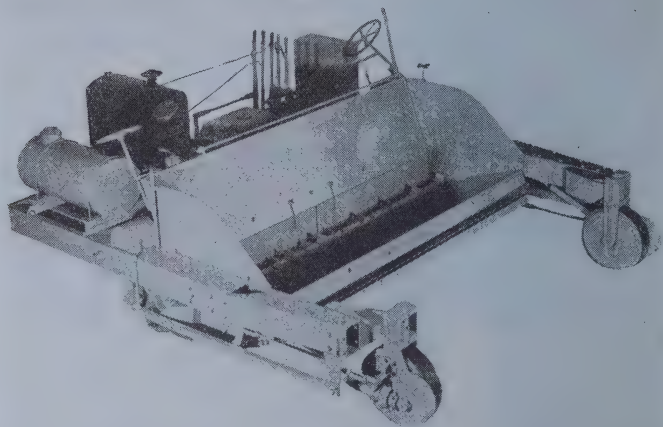
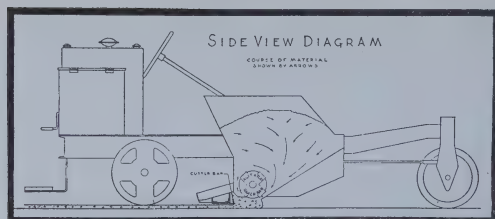
By F. L. DAKE

Treasurer, Adnun Engineering and Manufacturing Co.

Although asphalt as a paving material enjoys a number of well-known advantages, the industry a few years ago was facing a rather critical future, due to the costs that present methods of paving necessarily involve. Of these, perhaps the most burdensome had been the cost of spreading the mix after its delivery to the job.

So vital is this question that many of the best minds in the industry have long suggested the need for mechanical spread-

ing. However, many factors are involved in the operation of any such machine, and one of the obstacles originally claimed was the possibility that such machines, if produced at all, might be cumbersome, complicated, subject to breakdown and delay, and excessively costly in price, in maintenance or operation. In addition it was feared that such machines might be inaccurate in spreading, they might not form crowns or bank curves, or, finally,



View of Adnun Black Top Paver

the reduction in cost or the saving in time which they might effect would possibly offer so little advance over previous methods that the advantages would hardly be worth while.

Nevertheless, to a large extent the future expansion of the asphalt paving industry rests on the production of machinery which will supersede hand work because it will do the work enormously faster, more accurately and at far less cost. It is my pleasure to assure you that the problem has apparently been solved.

There are, as you know, several different types of mechanical asphalt spreaders on the market today, and I am assured that in most cases they are doing excellent work. All of them, and other mechanical advances which promise to help your industry, are worthy of your serious consideration. Other industries have profited by the adoption of new mechanical methods, and your industry should prove no exception.

I do not feel competent to discuss in detail any type of mechanical spreader except the one with which I am personally

familiar. Therefore, if you will permit me, I shall go into some detail regarding the mechanical asphalt spreader with which I am most familiar. I ask that you consider my remarks not as commercial propaganda for a particular machine but rather as a revelation of the extent to which your spreading problem has already been solved.

I can state to you that there are in existence right now mechanical asphalt spreaders, several of which in actual use on various jobs have done better work than can possibly be done by hand, so rapidly that mixing plants cannot keep up with the spreading machines, utilizing any type of bituminous aggregate, and using not more than three men and sometimes only two. The first cost is reasonably low, operation is simple, upkeep promises to be small, and the cost per yard of pavement is substantially reduced.

This mechanical asphalt spreader is known as the Black Top Paver and is the result of aggressive experiment and actual use over a period of two years. It is made by the Adnun Engineering &

Manufacturing Company, of Nunda, N. Y., a subsidiary of The Foote Company, makers of Multi-Foote Pavers for concrete roads.

First, I plan to tell you about the machine itself and then about a few of its on-the-job performances.

The frame, approximately twelve feet wide and thirteen feet long over-all, is supported in the rear by two steel rollers. The front wheels, rubber-tired, project well ahead of the machine itself, providing an extremely long wheelbase. It has four wheel drive and is powered with a twenty-four H.P. gasoline motor.

A steel hopper ten feet in width extends across the central portion of the machine. This hopper has an adjustable front end for varying the width of the opening at the bottom and regulating the flow of material from the hopper onto the sub-grade. Parallel with the opening in the bottom of the hopper is a raker bar with adjustable raker teeth pitched at an angle so as to distribute the materials evenly throughout the length of the hopper, break up any lumps and assist the flow of material from the hopper onto the sub-grade.

Directly at the bottom and rear of the hopper is a reciprocating cutter bar having undercut beveled teeth, not unlike those on a mowing machine, which cut off the material as it comes from the hopper and passes over it with a reciprocating motion, compressing and leveling it off in measured thickness anywhere between one-half inch and three and one-half inches and in any width up to ten feet. Once set, the adjustment produces the same width and thickness accurately until changed. The machine also crowns the surface and banks curves. Edges of the spread material are cut off square. Butt joints are made that are not detectable when rolled.

To load the hopper, a truck backs up between the front wheels. The average six to eight ton truck usually has to dump three times before being empty. After a short period of familiarity, very little time is lost in discharging a truckload of material, varying with the type of material and other factors from four to eight minutes. In some cases the spreader is not halted for loading, the truck and spreader moving ahead together at the same speed, the hopper being filled while it continues

spreading asphalt. Trucks are thus released quickly for return to the mixing plant, and fewer trucks are needed, per ton of material.

The spreader has three speeds—ten feet and twenty-five feet per minute in operation, both forward and reverse, and a speed of 150 feet per minute for traveling.

The number of men required does not exceed three.

Now that we understand something of the machine itself, let us consider some of its past accomplishments. Remember, the statements I am making are not guesses or estimates. They are based on actual experience with these machines on more than half a dozen jobs in New York State and Ohio during the past season.

First, it lays a better and smoother road surface or binder course than has been possible by hand methods.

Second, the entire raking crew is replaced by two or three men who operate the machine and assist in unloading trucks, thus releasing labor for work elsewhere.

Third, a course up to ten feet wide and three and one-half inches thick can be laid, under favorable conditions, at the rate of twenty-five feet per minute. This would yield approximately two and one-half miles in a nine hour day, if the spreader could be supplied with material fast enough to keep it at work continuously. As yet, no mixing plant or trucking service has been able to supply the machine with material as fast as it could be spread. As a result, the machine is idle a good part of the time, waiting for material.

Fourth, on a prepared roadbed, material is laid in uniform thickness, varying from one-half inch to three and one-half inches, as desired, with straight edges.

Fifth, on an uneven roadbed the long wheelbase automatically keeps the machine practically level. Thus depressions are filled up to the level of the cutting bar, producing a smooth surface which, after rolling, shows practically no variation, giving a smooth riding surface with no bumps.

Sixth, surfaces are crowned and curves are banked with a uniformity not attained with hand labor.

Seventh, the machine handles with equal success any type of bituminous material now on the market—hot mix, cold mix and emulsified or cutback asphalt mixes.

Eighth, forms and headers are not needed. The spreader works just as well on a country road as where headers or curb and gutter are used, due to the fact that the front wheels run directly on the subgrade and the rear rollers on the freshly laid surface.

Ninth, edges are trimmed square and butt joints made which cannot be detected after rolling.

Tenth, the machine uses material which has hardened into lumps and which cannot be laid by any other known method. This material, now being thrown away at considerable loss, is effectively salvaged, effecting an important economy.

Eleventh, varying widths of road can be laid. For instance, an eighteen foot road could be laid one strip ten feet wide and another of eight, or two strips both nine feet wide.

Twelfth, initial compression and more uniform texture are obtained by the action of the beveled teeth on the cutter bar.

Thirteenth, no definite figures can yet be given as to the maximum amount of road surface that can be laid in a day. This depends largely upon the efficiency of the organization, the size of the mixing plant and other individual factors. With continuous operation at high speed the machine has a capacity to lay fifteen hundred feet of pavement per hour, but on none of the jobs to date has sufficient material been supplied to keep the machine in continuous operation.

Lastly, engineers and contractors who have seen the machines in operation have been outspoken in their enthusiasm at the results attained, both as to speed of operation and quality of work produced.

The need for an economical and better means of laying a smooth riding surface without the use of expensive form setting or headers has now been met, and with the increase in size of mixing plants this method of laying Black Top bids fair to open up an entirely new era in asphalt road surfacing.

Planing and Smoothing Old Asphalt Surfaces Killefer Road Disc or Planer

By H. W. SCHARBER
Killefer Manufacturing Corporation, Ltd.

Mr. Chairman, and gentlemen of the Conference: As the southern representative of the Killefer Manufacturing Corporation, Ltd., I appreciate the opportunity to present some facts relating to the Killefer Road Disc or Planer.

This equipment is not new—it has been successfully and economically used on the Pacific Coast for more than 14 years but with the very attractive water transportation rates now in effect from West Coast ports to points like New Orleans, Baltimore, Philadelphia, New York, etc., our market has expanded and the attention of road and street authorities in the central west and east is being attracted.

In the limited time at my disposal I will endeavor to adhere closely to the suggested subjects to be discussed.

1.—The Purpose To Be Accomplished by This Equipment

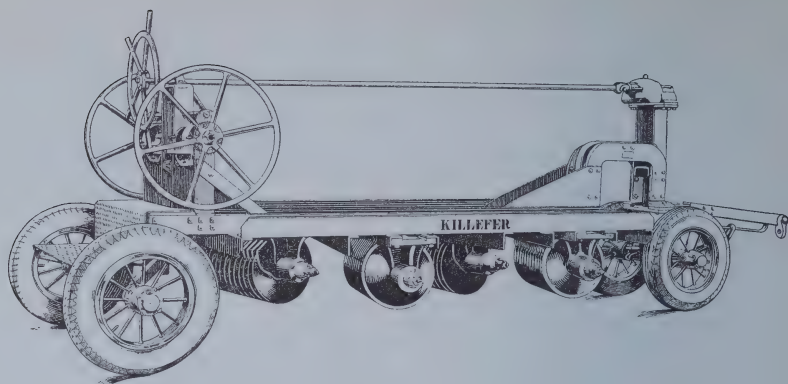
In September, construction and maintenance periodicals carried an advertisement by the Asphalt Institute under the heading: "Scrapping of Old Pavements Needless." In this advertisement it was pointed out that initial investments in pavements on the public highways were so large as to make their conservation imperative. The Killefer Road Disc or Planer economically aids in this conservation program by successfully planing or shearing the waves or bumps from old asphalt, asphalt-macadam surfaces, pocketed oiled roads, etc. This results in securing a smooth reconditioned road surface with the expenditure of a minimum of effort and at a very low cost.

In many instances this equipment is used to maintain roads or streets in a smooth condition making resurfacing unnecessary—where resurfacing is decided upon the planing process will provide a smooth, even surface without damage to the base, which is absolutely essential.

A highway engineer of note who had witnessed the operation of a Killefer Road Disc in a central western city during the past summer made the following statement: "This street department had apparently carried the smoothing operations to a greater degree of finishing, and the results were of such high quality and the discs cut through old macadam even, so thoroughly, that I have come to the opinion that you are altogether too modest in the claims you are making for your equipment. I believe that almost any kind of bituminous pavement can be successfully smoothed and the streets that are now rough and uneven can be salvaged and made into smooth-riding thoroughfares at a nominal cost."

To further set forth the purpose to be accomplished by this equipment, we quote from an address given by Mr. F. V. Reagel, Engineer of Materials, Missouri State Highway Department, at the meeting of the Association of Asphalt Paving Technologists in Detroit, January 1932, "A road that is to be re-oiled is usually gone over by the Killefer Road Disc prior to the application of oil. This machine consists of four sets of steel discs set at a slight angle to the center line of the road so that the weight rests on the discs. The discs turn as the machine proceeds, resulting in a row of narrow longitudinal cuts produced by shear. This action does not produce or permit progressive skinning or peeling. The axles on which the discs are mounted can be raised or lowered as may be necessary to make more shallow or deeper cuts in the surface. Those not familiar with this piece of equipment will be interested to find that it furnishes a very efficient method for smoothing out almost any type of bituminous surfaces."

I believe that these quotations establish the purpose for which the Killefer Road Disc is intended.



The Killefer Disc Machine

2.—The Underlying Principle of the Operation of This Equipment

The objective sought by the use of this equipment is to economically and quickly plane and smooth rough bituminous surfaces, improving them for traffic and, where resurfacing is contemplated, make it possible to conserve many good road bases that would otherwise be torn up and re-paved at a tremendous expense.

3.—Design

The No. 4A Killefer Road Disc weighs 7475 pounds, is furnished either with plain steel tires and plain bearings or heavy duty pneumatic tires and Timken bearings—the prevailing demand being for the latter wheel equipment. Under the frame is found four disc gangs, each gang consisting of 12 disc blades 20" in diameter, $\frac{5}{16}$ " thick, these blades are heat-treated and are spaced 2" apart, so as to produce a shearing effect as the machine moves forward. The raising and lowering device of this Road Disc is all-important—carefully machined adjusting screws are used and it is possible to control the cutting depth of the disc gangs even to $\frac{1}{32}$ ", and the disc gangs will maintain their position wherever placed, thus preventing gouging or damaging of the road base.

The wheel base when the disc gangs are in cutting position is 15' 6" and the length overall is 21' 6"—this includes the hitch. The cutting adjustment by means of the screw system also enables the disc gangs to fit the contour of the road as the disc gangs and frame can be lowered on one side or the other, or run perfectly level, as desired. Scrapers are provided for

cleaning debris from the disc blades; bearing take-ups in the disc gangs are available, the rear platform on which the operator stands affords easy control of the raising and lowering device, permitting splendid visibility so that the operator can observe the condition of the road ahead, and be prepared to change the adjustment of the gangs to meet the approaching conditions. The wheel arch at the front end of the machine permits of short turning at right angles and the equipment is so designed that it may be operated with a 20 to 30 horse-power tractor or the ordinary trucks used in road work.

4.—Operation

This equipment should be operated beginning at the center of the road and continuing to plane the surface to the outer edge. The depth of the cut depends upon the material to be planed, but on most surfaces the front gangs should be operated at about a depth of $\frac{1}{2}$ " and the rear gangs operated at a cutting depth of approximately $\frac{1}{2}$ " to $\frac{3}{4}$ ". If the surface is very bumpy or rough the front gangs should be set to just cut through the tops of the bumps; the rear gangs should be set a little deeper to complete the leveling process. The materials which this Road Disc is intended to plane or smooth yield best when the temperature is from 70 to 80 degrees or warmer.

There is nothing really complicated about the operation of this Road Disc—experience is the best teacher and a two-man crew, one for the tractor or truck and the other for the Road Disc, will soon become efficient in its use.

5.—Possible Coordination with Other Equipment

The Killefer Road Disc may be followed immediately by multiple blade maintainer or a blade grader when cutting a surface for complete reconstruction such as road-mix, etc., which mixes the loose material and moves it to any depression or to the side; the depressions are filled, and the entire surface is smoothed. I wish to mention here that the rear end construction of this Planer is such that a blade grader may be attached and the two pieces of equipment worked in tandem. The loose material will re-bind frequently with the surface, particularly if a re-oiling operation is performed within a reasonable length of time.

At one time in Pennsylvania enough material was planed from an old oiled surface road to assist in building shoulders 2 feet wide on each side. In this particular operation a blade grader was used to move the material from the center to the side of the road.

6.—Capacity, Economy and Cost

With the Killefer Road Disc having a cutting width of 48", it is very easy to determine its capacity by the speed at which it is pulled by the tractor or truck. On very rough surfaces or very hard

surfaces it is usually necessary to make several cuts to obtain the desired results, but up to the present period no other known method has been developed to successfully plane bituminous surfaces in so short a period and as economically as this work can be accomplished with the Killefer Road Disc or Planer.

Speaking of economy—in Indianapolis during July of this year a stretch of 1000 ft. of a 42 ft. rough, asphalt street was completely smoothed or planed in three hours and 45 minutes—ten tons of good asphalt were planed off, this material was trucked away and conserved for patching. After charging up \$18.45 for time, depreciation, gas and oil, the operation showed a profit instead of an expense. This same performance has been duplicated in many cities.

A careful check-up during June of this year on one mile of asphalt road 22 ft. wide, where retreading was to follow, showed that the mile surface was completely smoothed in one day and a half, and the cost of the Killefer planing operation as tabulated by the County Road Department gave the figure at \$27.60 for the mile. This amount of \$27.60 includes time of tractor driver, machine operator, gas, oil and depreciation. This ties in very closely with the results obtained in Kansas, Ohio, California and other states.

Miscellaneous Equipment

By RALPH C. HEATH
Mgr., Iroquois Dept., The Barber Asphalt Co.

Steam Jacketed Pump

The Iroquois steam jacketed pump is a pump of the single acting plunger type operated by means of a direct acting steam cylinder. This pump was designed for pumping materials which are extremely viscous or solid at ordinary temperatures and which require heating in order to promote a fluent condition; and especially to handle materials containing a mineral matter or other abrasive which is detrimental to the majority of pumps in causing wear which reduces the life of the pump. Owing to the simplicity of construction and the small number of parts involved, as well as the materials used in construction, the wear is reduced to a minimum and the life of the pump is greater than any other on the market now used for a similar purpose. This pump was primarily designed for handling Trinidad Asphalt but will handle equally well all types of asphalts as well as other heavy, viscous materials.

A steam jacketed casing entirely surrounds the plunger, stuffing box and the valves so that none of these parts can fail to operate on account of undue cooling of the liquid in the pump chamber.

The valve equipment of the pump con-

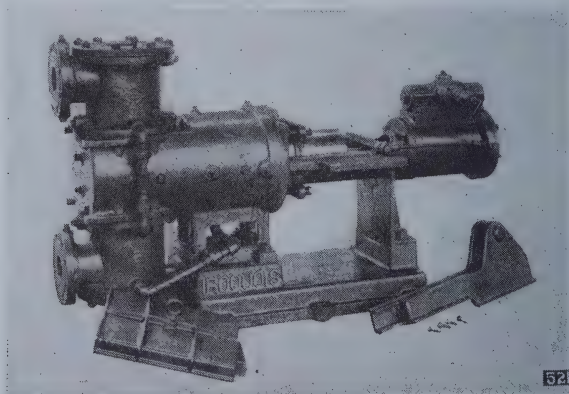
sists of two hollow bronze balls seated on carefully machined steel plates. One of the balls is a suction valve and the other the delivery valve. They are held in proper position over the seats by means of cast iron ball cages. The removal of the cover plate at the top of the vertical valve shaft permits the withdrawal of the whole valve mechanism. This can be done without disturbing the suction and delivery piping.

The pump has a minimum of working parts, there being only three moving parts which operate at slow speed: namely, the piston and the two balls. Large working surfaces are presented to the material being handled, thereby reducing the wear and increasing the life of the pump.

The plunger is constructed of a special chilled cast iron which presents a hardened surface having an extremely long life.

On account of the large port openings and the hammer effect of the balls the Iroquois pump can be used to handle materials which have not been thoroughly strained without great damage. It is desirable, however, in order to secure efficient operation to pass the material being pumped through a steam jacketed strainer before it enters the pump.

Large straight passages for the liquid being pumped are afforded instead of the



Iroquois steam jacketed pump

narrow, crooked passages usually present in the majority of pumps.

The pump is simply constructed, having no parts to adjust and therefore requiring little expenditure for repairs and maintenance.

The Iroquois pump is operated with an ordinary reciprocating pump steam end of simple construction which requires a limited amount of attention and repairs.

The construction of the pump affords accessibility to all working parts with a minimum of effort.

In operating the pump it can be stalled by closing off the discharge line and subsequently any by-pass arrangement with a relief valve or with a stand pipe is unnecessary.

A special piston type packing has recently been developed which, together with the hardened plunger has materially reduced leakage at the gland where the piston enters the cylinder; in fact, with proper care and tension in the gland, this leakage can be absolutely eliminated.

The figure shows the general arrangement of the pump with covers over the valve mechanism and plunger removed, and indicates the rugged construction. In this figure the packing gland and plunger can be noted.

Steam Jacketed Piping

Steam jacketed piping saves much delay and trouble in handling paving grades of asphalt. Its use also permits handling

bulk shipments in place of barrel shipments.

Following is approximate saving that can be effected with steam jacketed installations:

There is an average of 6.3 barrels to a ton of 2000 lbs., the barrels weighing approximately 20 lbs. each, resulting in a saving of 126 lbs. of asphalt per ton purchased.

126 lbs. Asphalt @ .0108 per	
lb.	\$1.36
126 lbs. Freight saving @ .305	
per 100 lbs.	.384
Package Differential	3.50

Total Saving in Material and	
Freight per ton	\$5.244

In addition to the above mentioned savings per ton you can figure the cost of unloading, storing the barrels and then the labor stripping and charging present supply tanks. In addition to this a saving will be realized from losses caused by asphalt adhering to barrels as presently used. Steam consumption will be cut to a minimum since asphalt will be heated in tank cars before unloading and requires less steam to keep in a liquid state.

Surface Heater

The surface heater is employed for heating the pavement to such temperature as will permit its ready removal by raking. It is essentially a steel hood under which



*Views of steam jacketed piping, showing
bypass arrangement at connections*

gas-fired torches are placed so as to direct a high heat against the surface of the pavement to be removed without affecting adjacent areas.

Asphalt Paving Tools

Before offering Iroquois tools to the purchaser they were perfected through experience gained by actual use in our own paving operations. We learned the weak points and did the experimenting instead of our customer.

The first asphalt pavements were laid in this country by our company and, as pioneers and leaders in the industry, we were compelled to design and build most of our equipment. The asphalt tools illustrated and briefly described are the result of wide experience and are mostly of our own design. We know they are right and offer them as the most suitable for the purposes intended.

Asphalt Tampers and Smoothers

The Iroquois Tampers and Smoothers are made in the following manner:

Inch and a quarter steel pipe is procured, which is used for handles and which is welded under an air hammer to



Asphalt Smoother



Asphalt Tamper

a steel stub, which is, in turn, cast into the foot of the Tamper or Smoother. These castings are cast in chill molds which give us a casting with a hard surface, which enables the tool to stand up under high temperatures, hold the heat, and give a longer life than if the castings were made from green sand molds.

Asphalt Tamper 8 in. x 6 in.

(standard) 35 lbs.

Asphalt Tamper 8 in. x 8 in. . . . 37 lbs.
 Asphalt Tamper 6 in. x 6 in. . . . 28 lbs.
 Asphalt Tamper 4 in. x 4 in. . . . 20 lbs.
 Asphalt Smoother 10 ½ in. x 6 ½ in.
 (standard) 46 lbs.
 Asphalt Smoother 14 ½ in. x 7 ½ in.
 68 lbs.

Asphalt Shovels



Especially designed with flat square point bowl for asphalt work. Length of bowl 12 in., width of bowl 9 ½ in. Furnished with solid steel socket, which prevents burning the wooden handle. Approximate weight, 5 lbs.

Asphalt Rakes

Especially designed and made for the severe service required of a rake for hot asphalt and other bituminous paving work. Stamped out of a solid steel plate and provided with a long, steel shank, thus protecting the wooden handle from the heat.

Length of head, 15 ½ in., length of tines, 3 ½ in.; number of tines, 14; length of steel shank, 17 ½ in.; length of handle from head, 6 ft. 6 in. Approximate weight 5 ¼ lbs. Rakes with handles 7 ft. 6 in. are also carried in stock. Approximate weight 5 ½ lbs.

A limited stock of rakes is carried similar to those described above except that the tines are only 2 ½ in. long. Approximate weight 5 lbs.

Asphalt Patching Hoes



When patching or resurfacing asphalt pavements these hoes are used for scraping off the old surface, while it is hot, after the surface heater has been applied.

Blade, No. 10 steel; 10 ¼ in. wide:

RALPH C. HEATH

9 in. high, with stamped teeth, 1 in. pitch by 1 in. deep.

Handle, 6 ft. 0 in. long of $\frac{3}{4}$ in. steel pipe welded to a steel stub, 12 in. long which is treated and on which the blade is clamped by nuts and washers on each side.

Approximate weight 11 $\frac{1}{2}$ lbs.

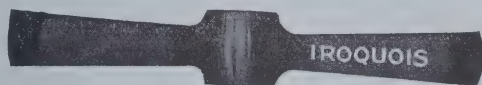
Asphalt Cutters

Used for cutting out old asphalt pavements. Made of tool steel with tempered

cutting edges. Provided with a double cutting edge and can be reversed on the handle when cutting edges are worn. Can be used twice as long as the ordinary single-eye cutter. Pick handles are used with these cutters, and are not supplied unless especially ordered.

Length between cutting edges 20 in.; width of cutting edges 3 in.

Approximate weight 11 lbs.



Asphalt Cutters

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Oil Mat Surfaces

By W. V. BUCK
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The general experience of the administrators of highway activities indicates that the public demand is for improved roads which will effect an immediate reduction in the operating costs of vehicles using the highways, together with a definite curtailment of public expenditures.

An improvement program for a highway system under the current revenue plan must be so designed as to meet this demand.

The state highway system of Kansas is comprised of 8,690 miles of roads, and its improvement has made rapid progress only during the last seven years. The development of a large mileage of light type surfaced roads was begun in 1925 when the advent of the sand-gravel surface became an important factor toward a definite program of stage improvement. The insistent demand for this type of road resulted in its rapid development, and by June 30, 1930, there were more than 3,000 miles of light type untreated surfacing on the state highway system. When an extensive mileage of these surfaces became connected, a concentration of traffic was immediately noticeable on the system and the deficiencies of the sand-gravel types rapidly appeared under this heavy traffic. The roads became dusty and corrugated under dry weather conditions and were equally sloppy and unsatisfactory for heavy traffic during extended rainy seasons.

Improvement Methods

The method of constructing the light type surface in Kansas consisted of placing a windrow of the surfacing material on one shoulder of the road and periodically spreading a small portion of this over the road surface under maintenance operations. The existence of this windrow on the roadbed created an additional hazard to traffic. While the improved road was far superior to the unsurfaced sections, its use developed an immediate demand for some type of surface which would eliminate these hazardous and unsatisfactory conditions.

Early in 1930, the State Highway Department began some experiments in the development of a surface treatment which would eliminate some of the objections to the sand-gravel type, preserve the original investment in the road and provide a safer road condition.

The first experiment consisted of a section of road approximately seven miles in length constructed under the methods developed by the New Mexico Highway Department.

The materials used in this work consisted of 1,200 cubic yards of sand-gravel aggregate and 17,000 gallons of light asphaltic road oil per mile.

Typical analyses of the aggregates used are shown below.

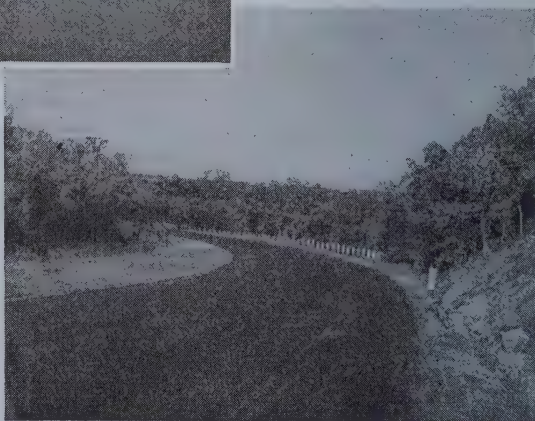
Sieve Size (Sq. Mesh)	Per Cent Retained								Wt/cu. ft.	
	3/8	4	8	14	28	48	100	200	D & R	
Pit Run Aggregate .	5	12	22	35	57	91	98	99	102	
Screened Aggregate .	15	33	62	91	98	99	99	99	112	
Volcanic Ash (Silica)								40	60	
Finished Aggregate .	9	21	39	61	70	84	92	95	118	

*U. S. 96 — Ness
County — 1932
Construction. Sand
Gravel Aggregate.*



*(Below)
U. S. 75—Osage County—
1931 Construction. A job
which was remixed during
1932. Water in the subgrade
caused some trouble.*

*(Above)
U. S. 73W—Labette
County — 1931
Construction. Chat
Aggregate. Typical
view of mat road
showing well defined
lines of vegetation
along the sides.*



Note visibility of white guard fence posts on curves. Flat curves with correct super-elevation are more easily maintained on oil mat surface.

The aggregate was developed by combining pit run aggregate with a special screened aggregate and the addition of volcanic ash or silica, producing an ag-

gregate weighing 118 lbs. per cu. ft. The oil used contained 61 per cent 100 penetration asphalt.

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The following is a typical analysis of oil used:

Specific Gravity	1.05
100 Penetration Asphalt (per cent)	61
Viscosity 60°C (Engler)	16
Flash Point °C	143
Ductility of Asphaltic Residue (cm)	99.8
Solubility in CS ₂ (per cent)	2.25
Loss at 163°C, 50 grams, 5 hours (per cent)	

The pit run material was washed over a vibrating screen to obtain the screened aggregate. The fines, or the material passing the 200 mesh sieve, were obtained from a deposit of volcanic ash approximately twenty miles from the project. About two parts of pit run material were combined with three parts of screened aggregate and the volcanic ash was then added so as to obtain a finished aggregate of the proper gradation.

The manipulation on this work was done with state equipment and was under the direction of a superintendent loaned to Kansas by the New Mexico Department. The cost of this construction was \$4,650.00 per mile. This road has been in service for two years; is in satisfactory condition at the present time, and has required very little maintenance.

Low-Cost Surfacing

This type of road has proven satisfactory, but due to the large mileage on the Kansas Highway System and the limited funds provided for original construction, it became necessary to develop some suitable surface which would cost approximately \$2,000 per mile. With this objective in view, the Department established a few short projects during 1930 using a blotter treatment surface. This consisted of applying a penetration coat of approximately .5 of a gallon of 60-70 asphaltic road oil per square yard on an earth or sand-gravel subgrade. After this application had thoroughly penetrated, a second treatment was placed on the surface in the amount of .5 of a gallon per square yard and the surface was immediately covered with approximately 300 cubic yards per mile of the standard sand-gravel surfacing material which had been previously windrowed along one side of

the road. This method produced an oil mulch surface which was comparatively waterproof and dustless.

The advantages of this surface over the sand-gravel type were quickly sensed by the traveling public and the demands upon the Commission to increase the mileage of this treatment soon became quite extensive. Accordingly, early in 1931, contracts were awarded for approximately four hundred miles of surface treatment using asphaltic road oils under the blotter method. At this time, members of the Department investigated work that had been done in other states and particularly in Minnesota, where considerable advancement had been made in this type of construction. It was found in Minnesota that under progressive treatments over a period of years a fairly substantial bituminous mat had been developed. After observing this work, it was immediately decided to revise the methods of construction in order that a mat might be attained with the original treatment rather than to develop the road surface with a mulch under maintenance methods.

The requirements for 1931 construction included the application of from .5 to .7 of a gallon of 60-70 per cent asphaltic road oil per square yard as a penetration over the entire width of the roadway, the addition of the proper amount of 60-70 per cent asphaltic road oil to approximately 300 cubic yards of mineral aggregate per mile, and the manipulation of this material until the aggregate was thoroughly coated. This was uniformly spread over a width of approximately twenty-seven feet and opened to traffic.

After a few weeks observation of these mats under traffic, it developed that some projects responded with a substantial mat

ASPHALT PAVING CONFERENCE, 1932

while others began raveling and showed tendencies to revert to the mulch type treatment.

Experience with the heavy mat project and the mulch construction which had been most successful, indicated that it would be necessary to use aggregates having an ideal gradation and a maximum density similar to those used in the construction of sheet asphalt, Topeka mix or comparable asphaltic concrete types. Those mats which showed unsatisfactory results were reconditioned by the addition of fines, that is, material passing the 200 mesh sieve and such other aggregates as were necessary to fill the deficiencies shown from the sieve analysis of the original mineral aggregate.

Through the co-operation of the contractors to whom this type of work had been awarded, immediate arrangements were made to investigate and build up all materials which had been delivered on the road for bituminous mat construction, so that any deficiencies in the material as to the gradation necessary to produce a satisfactory mat would be provided. A substitution in the specifications for materials that had not been delivered was made to provide a properly graded aggregate.

With these corrected procedures on work which had already been placed under contract, and the establishment of

a definite set of specifications for new contracts to be awarded for 1931 construction, a program of 766 miles was satisfactorily completed during that year.

Observations on the work completed in 1931 led to several changes in the methods specified for the 1932 program.

Complete investigation of materials was undertaken by the Department, and revisions made where necessary to correct in future work, the apparent defects found in previous construction methods.

Some mats indicated a tendency to corrugate or roll, while others raveled, oxidized, or showed similar signs on an unstable condition.

Investigation disclosed that the mats in which more cubic yards of material were used per mile produced better results and that the proper selection of materials, revised construction methods and improved specifications were essential to attain the most satisfactory road surface. It was also disclosed that two main items must be specified very definitely for oil mat surfacing; that is, mineral aggregate and asphaltic road oil or similar bituminous material.

Specifications and Test Results

The specifications for the road oils in Kansas during the past two years appear in Table No. I. The road oils referred to

TABLE NO. 1
KANSAS ROAD OIL SPECIFICATIONS

Test	GRADES OF OIL+				
	1931 60-70	70-80	55	1932 65	75
Specific Gravity at 77°F, not less than	0.980	0.980	0.980	0.980	0.980
Flash Point °F, not less than	212	212	212	212	212
Viscosity, Saybolt Furol at 122°F	40-180	200-350	40-100	150-300	350-500*
Ductility of asphaltic residue (100 penetration) at 77°F, not less than	100	100	100	100	100
Loss, 50 grams in 5 hours at 325°F, not more than	8.0	8.0	10.0	8.0	8.0
Bitumen Soluble in Carbon Disulphide, per cent, not less than	99.0	99.0	99.0	99.0	99.0
Bitumen Insoluble in 86° API Naphtha, per cent, not less than	11.0	14.0	8.0	13.0	15.0
100 Penetration Asphalt Content, per cent	60-70	70-80	55†	65†	75†
Water and Sediment, per cent, not more than	2.000	2.000	2.000	2.000	2.000

+Grades are defined from per cent of 100 Penetration Asphalt.

*Traveling Plant shall be 600-900.

†Minimum per cent.

TABLE No. 2
AVERAGE RESULTS OF TESTS ON ROAD OIL USED IN KANSAS CONSTRUCTION DURING 1931
60-70 OIL

Oil	No. of Tests	Specific Gravity at 77°F.	Flash Point °F.	Specific Viscosity Saybolt Furol at 122°F. Sec.	Ductility 77°F.	Loss Per Cent. 325°F. 5 Hrs.	CHARACTERISTICS OF RESIDUE			
							Penetration 77°F. 100 _g 5 _s	Per Cent. Bitumen Soluble in CS ₂	Per Cent. Bitumen Insoluble in 86°API Naphtha	Per Cent. Asphalt at 100 Penetration
A	115	1.003	297	155	100	4.12	99	99.62	13.14	66.9
B	202	1.045	280	109	100	4.99	95	99.76	17.10	65.9
C	251	1.036	262	118	100+	4.15	98	99.84	20.24	67.0
D	244	1.034	255	115	100+	5.74	88	99.67	27.36	66.8
E	103	1.034	300	164	100	4.45	99	99.34	12.64	68.2
F	62	1.041	320	138	100+	3.61	96	99.20	18.97	65.2

70-80 OIL										
A	132	1.016	302	312	100	3.69	98	99.68	16.20	72.5
B	209	1.050	311	310	100	3.83	95	99.75	21.27	74.6
C	164	1.050	333	325	100+	2.68	100	99.82	23.00	74.2
D	200	1.045	282	293	100+	5.18	91	99.65	29.06	73.8
E	125	1.046	304	307	100	4.73	100	99.61	15.45	72.8
F	37	1.047	324	302	100+	2.80	99	99.44	19.16	71.4

TABLE No. 3
AVERAGE RESULTS OF TESTS ON ROAD OIL USED IN KANSAS CONSTRUCTION DURING 1932
55 OIL

Oil	No. of Tests	Specific Gravity at 77°F.	Flash Point °F.	Viscosity Saybolt Furl at 122°F. Sec.	Ductility 77°F.	Loss Per Cent. 325°F. 5 Hrs.	CHARACTERISTICS OF RESIDUE				
							Penetration 77°F. 100g ^{5s}	Per Cent. Bitumen Soluble in CS ₂	Per Cent. Bitumen Insoluble in 86°API Naphtha	Per Cent. Asphalt at 100 Penetration	Water and Sediment
A	32	.993	257	91	100+	6.86	104	99.72	9.28	61.86	0.9
B	82	1.045	300	79	110	6.21	100	99.89	14.55	61.91	1.0
C	22	1.032	264	63	100+	4.36	97	99.71	15.82	61.77	0.6
D	5	1.036	277	94	100+	4.98	98	99.80	11.98	64.26	0.3
E	32	1.051	257	91	100+	9.30	100	99.77	12.51	63.84	0.3
F	17	1.037	306	79	100+	4.07	93	99.50	11.03	58.60	0.9
H	4	1.070	261	90	100	5.49	93	99.50	16.39	65.00	0.8
I											

65 OIL

Oil	No. of Tests	Specific Gravity at 77°F.	Flash Point °F.	Viscosity Saybolt Furl at 122°F. Sec.	Ductility 77°F.	Loss Per Cent. 325°F. 5 Hrs.	CHARACTERISTICS OF RESIDUE				
							Penetration 77°F. 100g ^{5s}	Per Cent. Bitumen Soluble in CS ₂	Per Cent. Bitumen Insoluble in 86°API Naphtha	Per Cent. Asphalt at 100 Penetration	Water and Sediment
A	121	1.029	252	271	100+	5.95	95	99.73	16.50	72.47	1.3
B	138	1.048	255	266	110	5.46	99	99.80	17.69	74.33	1.0
C	72	1.046	318	204	100+	2.93	96	99.72	18.26	70.18	0.8
D	44	1.065	267	203	100+	4.58	99	99.76	16.70	70.35	0.1
E	232	1.065	266	226	100+	6.29	100	99.78	13.68	72.47	0.4
F	68	1.056	335	282	100+	3.01	98	99.63	16.35	70.30	0.7
H	16	1.038	300	253	100	3.38	94	99.41	14.20	74.10	0.9
I	28	1.001	250	238	100+	6.24	98	99.66	15.78	71.08	0.6

TABLE No. 3—(Continued)

75 OIL

A	91	1.030	259	446	100 +	5.76	97	99.52	16.27	75.65	0.5
B	108	1.060	265	391	100 +	5.40	103	99.84	20.32	77.41	0.2
C	51	1.047	340	425	100 +	1.85	97	99.74	18.52	76.16	0.9
D	37	1.068	298	476	100 +	3.16	104	99.78	21.17	76.47	0.3
E	192	1.059	286	456	100 +	2.64	100	99.70	16.09	78.07	0.4
F	17	1.061	335	459	100 +	2.88	101	99.69	20.69	76.00	0.9
H	33	1.042	295	366	100	3.87	92	99.48	17.36	77.50	0.9
I	19	1.010	270	482	100 +	4.20	96	99.48	16.75	76.30	0.6

75 OIL
(Plant Mix)

A	138	1.057	264	783	100 +	5.39	100	99.83	19.11	81.32	0.1
B	43	1.064	359	754	100 +	1.49	100	99.78	21.33	77.57	0.7
C	13	1.071	304	747	100 +	2.83	96	99.81	22.08	79.64	0.3
D	55	1.082	313	753	100 +	1.56	100	99.69	15.92	79.22	0.2
E											
F											
H											
I											

in this discussion are classified on the basis of the per cent of 100 penetration asphalt as determined by the method D-243-28T of the American Society for Testing Materials. For example, 60-70 road oil contains between 60 and 70 per cent asphalt, 55 road oil contains not less than 55 per cent asphalt, etc. It should be noted that during the 1931 construction season a much lighter oil was used than during 1932. During 1931, it was found that the 60-70 oil having a viscosity of 40 to 180 worked very well during moderate weather, but was not heavy enough when used as a penetration oil during hot months of the year. Mats constructed in 1931 containing 70-80 oil having a viscosity of 200 to 350 did not attain a sufficient hardness until after they had been laid for two or three months. With these facts in mind, it was decided to increase the viscosity of the 60-70 and 70-80 oil and to specify a lighter material, such as the 55 oil shown in the 1932 specifications for use as a penetration oil in cool weather or on very hard subgrade. It was also decided that it would be desirable to use a high viscosity oil in stationary or traveling plant work. In Table No. II are shown the average results of tests of road oils used during 1931, and Table No. III contains the results of tests of oil used in 1932 construction work.

An examination of the 1931 test results shows that there was a tendency on the part of the refiners to furnish oil having an asphalt content very close to the lower limit for 70-80 oil and well above the average for 60-70 oil. In several instances oil was furnished which had an asphalt content very near the top of the limit for 60-70 oil and the same oil, with a change in viscosity was furnished under the 70-80 specifications. In order to correct this condition, a minimum asphalt content was specified in the 1932 specifications, and a gap in the viscosity was left between the different grades of oil.

The 55 oil was specified so that an oil would be available which could be used for penetrating very dense subgrades and for use in cool weather.

Choice of Aggregates

The coarse aggregates used in the construction of mats in Kansas consist of

granitic sand-gravel, chats or crushed limestone. Sand or sand-gravel are obtainable from local pits in the western part of the state; also from commercial plants located along the Kansas and Arkansas rivers and their tributaries. Chats, or the tailings obtained from the processing of zinc and lead ores are available in the southeastern part of the State.

Aggregates of the proper gradation do not occur naturally in any section of the State. All of the materials are lacking in the sizes passing the 100 and 200 mesh sieves and those retained on the $\frac{3}{8}$ and $\frac{1}{4}$ inch sieves, therefore, in all of the jobs that have been built, using sand-gravel or chats, it is necessary that the aggregates be built up, either at the point of production or on the road by the combination of the sizes necessary to produce the desired gradation.

A large quantity of mineral aggregate has been obtained by the crushing of limestone from local ledges. A very desirable gradation was obtained with this material by the use of a crusher and a hammer mill, or of a hammer mill alone. Limestone aggregate from commercial sources has also been used. Crushed limestone is the only material from which mineral aggregate can be prepared directly without combining several different sizes.

Considerable attention is given to the maximum density of aggregates which may be obtained from the materials available, or in other words, materials furnished are combined in such proportions as will give the maximum weight per cubic foot in the dry and rodded condition. In many cases, it has been necessary to combine as many as four sizes in order to obtain the desired results.

The securing of material passing the 200 mesh sieve was one of the most difficult problems. It was found, however, after an extensive investigation that this material could be obtained in most sections of the State. In the western part of the State volcanic ash or silica is obtainable. In the central or eastern part of the State river silt is available and in the southeast corner of the State, the finely ground tailings from the processing of zinc ores, commonly known as chat sludge, can be obtained.

The curve shown in Figure I is used as a guide for the gradation of the ag-



U. S. 50S—Stafford County—1931 Construction. 1200 cu. yds. per mile.
Original mat job mentioned in paper.

gregates to be used in mat surfaces. It is required that materials be delivered to the road having a gradation approaching this curve or that different sizes be delivered in quantities such, that when combined, they will produce an aggregate having a gradation which will approach the straight

line shown in this curve. The Kansas specifications, as to the gradation of aggregates, are based on the permissible variation from the percentage retained on each sieve as shown by the curve. The gradation requirements as set forth in the 1932 specifications are as follows:

"Passing 1 inch mesh sieve	100%
Retained on $\frac{3}{8}$ mesh sieve, not less than	5%
Retained on 8 mesh sieve	25% to 50%
Retained on 28 mesh sieve, not more than	75%
Retained on 100 mesh sieve, not more than	85%
Passing 200 mesh sieve, from	12% to 20%

NOTE: When the mineral filler can be definitely controlled, as in a stationary mixing plant, 8% to 15% of the total mineral aggregate shall pass a 200 mesh sieve."

In the 1931 work, it was necessary to build up existing windrows, due to the fact that contracts were let for surfacing material rather than for mineral aggregates for mats, before it was decided to construct the mat type of surfacing. On every job, therefore, it was necessary to analyze the material on the road and to supply those sizes of aggregate necessary to produce a dense, well balanced aggregate.

Most of the 1932 projects did not have surfacing material on the road. Therefore, it was not necessary to build up existing windrows. On some projects the aggregates furnished were composed of crushed rock (for the per cent retained on the $\frac{3}{8}$ " sieve), sand-gravel,

fine sand (when needed), and silt or silica. On projects in the southeast corner of the State, the chat producers co-operated with the Department in producing a finished aggregate having the desired gradation. Limestone aggregate was furnished from either road side plants or commercial quarries on many projects.

After the mineral aggregate and the oil had been mixed and the mat was ready to lay down, samples of the mixture of aggregate and oil were taken at five hundred foot intervals and combined so that a representative sample of the mixture for every mile was obtained. The road oil was extracted from this sample by means of a Dulin rotarex, and a sieve analysis made of the aggregate. This extraction



1931 Construction Chat Aggregate. Picture taken August, 1932. Note how earth has washed away from oiled earth.

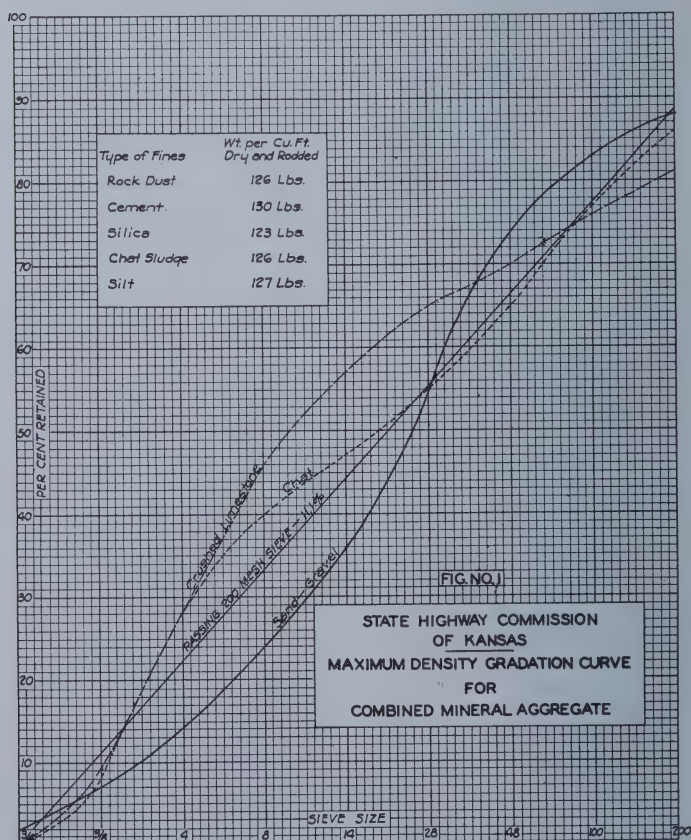


Fig. 1



U. S. 40—Trego County—1931 Construction. Sand-gravel Aggregate. Snow melts quickly from Bituminous Mat.

test was used as a control measure. If the Engineer found that the oil in the mixture was not correct, or that the gradation of the aggregates did not comply with the requirements, such changes were made in the rest of the project as necessary to correct the unsatisfactory condition.

Laboratory Research

Some research work has been done in the laboratory on road oils and aggregates. It was found that as far as the physical characteristics of road oils are concerned, that all of the oils furnished by eight refineries for use in Kansas were practically the same. *Field observations*



U. S. 40N—Cloud County—1931 Construction. Showing rolling mat due to water, possibly brought in through ledge formations.



U. S. 40—Trego County 1931 Construction. Showing the effects of moisture. When mat is laid down wet or on a wet subgrade it will shove, roll or wrinkle.

however, lead to the conclusion that the weathering properties of all oils are not the same, and, therefore, a test must be developed by a co-operative effort of Highway Departments and the refineries which will give information as to the resistance of road oils to the elements. This investigation also included work on the stability of various types of filler or fines available in the State, and the quantity of fines and oil necessary to produce the best results. The conclusions developed from these investigations are as follows:

1. That the value of mineral fines may be classified in the following order:

- a. Limestone or rock dust (Shale free)
- b. Silica or volcanic ash
- c. River Silt
- d. Chat Sludge

2. That to obtain the best results 10 to 20 per cent of the mineral aggregate must pass a 200 mesh sieve. Field experience indicates that the best results are obtained when the gradation of the aggregate permits the use of the minimum per cent of mineral filler.

3. That five to seven per cent of oil will produce the most satisfactory results.

4. That top soils and shaley material when finely pulverized and free from clods are satisfactory for use as fines in mineral aggregate. It has been found desirable to abandon the use of top soils due to the difficulty encountered in preparing them for use.

These investigations were used as a guide in determining the methods of procedure and the type of material to be used in 1932 work.

Construction Methods

In the construction of bituminous oil mats, there are numerous items which are necessarily more or less indeterminate, making it impractical to award contracts for the complete process. The following work is performed in Kansas with State forces and equipment, which are preliminary to the activities of the contractor who handles the manipulation and completion of the job:

1. The preliminary preparation of the subgrade.
2. The removal of unsuitable or the addition of suitable subgrade material and the construction of the necessary drains.
3. The windrowing of existing suitable material.
4. The addition of all necessary mineral filler on road mix or traveling plant mix jobs when roadside mineral filler is specified.

After the subgrade has been properly prepared by State forces, the aggregates are delivered on the road and placed in a uniform windrow. Where two or more aggregates are required to produce the finished mineral aggregates, the contractor is furnished with information as to the volume of the separate sizes which will be necessary. Each size is then delivered to the road and the total volume of material is thoroughly mixed in order to produce the desired gradation of the mineral aggregate. The aggregate is then placed in a uniform windrow by means of some mechanical device, and carefully sampled. A sieve analysis is made of the samples, and from such sieve analysis, any deficiencies in gradation are corrected by the addition of the sizes which may



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be necessary. The weight of aggregate per running foot of windrow is determined and this weight is used for the calculation of the necessary amount of road oil.

As a basis for computing the amount of oil in the mat coat, the following formula which has been developed by the New Mexico State Highway Department is used:

" $P = 0.02A + 0.07B + 0.15C + 0.20D$ in which

P = Percentage of oil by weight;

A = Per cent of material retained on a 48 mesh sieve;

B = Per cent of material between the 48 and 100 mesh sieves;

C = Per cent of material between the 100 and 200 mesh sieves;

D = Per cent of material passing 200 mesh sieve."

Variations from the quantities obtained by the use of this formula are necessary in certain cases.

When limestone aggregates having a high absorption are used, it is necessary to increase the percentage of oil by an amount necessary to take care of the absorption. When aggregates are used con-

taining an excessive amount of fines, the use of this formula without variation will result in larger quantities of oil than may be necessary. The variation from the quantity determined by the formula must be left to the judgment of the engineer in charge of the work.

The total quantity of aggregate required in the 1932 contracts was 575 cubic yards per mile. When the aggregate was supplied in two or more sizes, the combination resulted in a shrinkage of volume to the extent that the finished mat contained between 425 and 475 cubic yards of aggregate. When finished mineral aggregate was supplied, a total volume of 500 to 575 yards was placed in the mat.

Specifications for 1932 work included three general methods for the manipulation and construction of the bituminous mat. Regardless of the method used in manipulation, the application and the amount of the penetration coat to the subgrade were identical. As a general practice, the penetration coat was applied just prior to the manipulation of the mat.

The penetration coat, under 1932 specifications, consisted of the application of .5 of a gallon of 65 road oil per square yard for a width of approximately twenty-six feet. This application was given sufficient time to thoroughly penetrate into the subgrade before any mineral aggregate was spread over the penetrated portion. In some instances, the penetration coat was omitted until after the aggregate and oil had been properly mixed and ready to lay down, and this coat was then applied and given sufficient time to penetrate before the mat material was spread. This latter procedure has no particular advantage except in cases where the subgrade is well-compacted and has a covering of dust or other fine material.

Another alternate procedure on some projects was to apply the penetration coat on the entire project before the materials were delivered on the road. This procedure has a particular advantage if the work has been delayed into the latter part of the season, because the penetration coat must necessarily be applied during warm weather.

In all cases where the penetration coat has been applied as an operation prior to the delivery and manipulation of aggregates, it should be definitely determined that the subgrade is well compacted and in satisfactory condition to carry the necessary truck traffic.

In the road mix method, the mineral aggregate was dried, pulverized and uniformly spread over the road surface for a width of approximately fourteen feet. Asphaltic oil of the grade and in the amount determined by the engineer was then applied with a pressure distributor at a temperature not less than 125° F. nor more than 175° F.

Discs or harrows followed immediately behind the distributor for the purpose of preliminary manipulation of the mineral aggregate and the asphaltic oil. The manipulation was then continued with power graders either of the push or pull type, having a moldboard of from ten to twelve feet in length constructed with a radius of curvature of not more than fifteen inches. After the mineral aggregate and oil have been properly mixed, the combined material is windrowed down the center of the road.

The advantages of the road mix method are that all operations in the manipula-

tions of the mat tend to compact and improve the surface condition of the subgrade and it involves the use of equipment which can ordinarily be assigned to grading or routine maintenance work.

The second method of manipulation and mixing the mineral aggregate and oil used in 1932 construction was by means of a traveling plant. The mineral aggregate was hauled, dried and windrowed as described under the road mix method. The mineral aggregate was picked up, proportioned and mixed with the proper amount of asphaltic road oil by means of the traveling mixing plant and deposited in a uniform windrow behind the machine.

The traveling plant must be equipped with satisfactory measuring devices for accurately and uniformly proportioning the amount of mineral aggregate and asphaltic oil that enters into the mix. One of the most costly operations in the construction of this type of road is the removal of moisture from a partially mixed windrow of aggregate and oil, and due to the fact that the traveling plant completely mixes the oil and aggregate before it is deposited on the road, this difficulty is avoided. Other advantages of the traveling plant method include the possible operation of the equipment over an entire twenty-four hour period, thus appreciably increasing the season's production.

The third general method of mixing mineral aggregates and asphaltic oil for bituminous mat projects was handled by a stationary plant. When this type of equipment was used, the material was taken from the storage pile, through the artificial drier to the screens and then properly proportioned by weight and mixed in a pug mill with the correct percentage of asphaltic oil. The mixed materials are deposited in trucks, transported to the project and deposited in a uniform windrow on the previously penetrated road surface.

The type of bituminous mat constructed under Kansas methods involves the use of a relatively small quantity of aggregate over a large mileage of road. Due to the fact that there are no readily portable artificial driers of large capacity, it is impractical to use stationary plants except on projects where the total quantities involved for a separate set-up are large. The advantage of the stationary



Traveling Plant, showing the elevator picking up the dry material from the windrow.

plant lies in the fact that it is possible to control the gradation of the material and the moisture content to a much finer degree than with either of the other two methods. This method insures a better mixed and graded product and avoids the expense and delay of drying a long windrow of aggregate ahead of the oiling operations, which is necessary under the other two methods. The stationary plant has the same advantage as the traveling plant, in that it can be operated over a twenty-four hour period.

Following any of the manipulation methods that have been described, the material was uniformly placed in a windrow on the penetrated subgrade previous to spreading. Power graders of either the push or pull type were used in spreading the material to a uniform thickness over a width of twenty-two feet, adopting one of two methods for finishing the edges of the mat. The prevailing method in Kansas construction consisted of merely feathering this edge for a width of approximately two feet on each side of the mat. Another method which has been used quite extensively during the past season has been to prepare a wedge-shaped trench with a two inch maximum depth at the outside, thus forming a thickened edge for the completed mat.

The finishing of the road surface is accomplished by blading with graders equipped with pneumatic tires. Following this operation, the mat is thoroughly rolled with a pull-type roller weighing approximately five tons.

The final process in the completion of the bituminous mat road was the application of .3 to .5 of a gallon of 65 oil for a width of approximately five feet, extending from two feet inside the edge of the mat to the road shoulder.

Maintenance

The maintenance of bituminous mats constitutes an important part in its development and success. It is not always possible during construction to obtain the ideal proportions of materials and perfect manipulation on every job. The immediate maintenance operations on those projects which show early signs of surface defects is absolutely essential.

The construction of a large mileage of bituminous mats in Kansas led to the adoption of standard equipment and methods of procedure for handling the routine maintenance work. These types of roads have been divided into sections



Traveling Plant, showing the mixed material being delivered in a windrow on the penetrated subgrade, leaving the remainder of the road clear for penetration application.



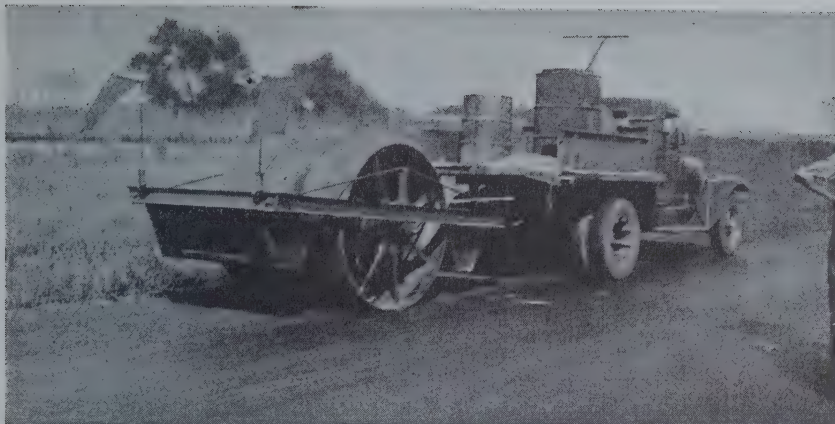
Device used by the Engineering Department for cutting out one lineal foot of the windrow. In order to determine the weight of each lineal foot of the windrow test samples are run from this same material.

of from twenty to forty miles in length, and a special 2-2½ ton maintenance truck with accessory equipment and two men assigned to each of these sections. The use of a substantial truck unit on this work is necessary to provide power for pulling a heavy roller and so that no outside assistance will be required for snow removal work.

Material stock piles are provided at intervals of about five miles along the road section. In some cases, these materials are taken from the mixed windrow during construction operations, or they may be mixed on a side road, loaded into trucks and hauled to the stockpiles. Where plant mixes are used, sufficient material for routine maintenance work has been obtained from the construction plant. Another method of handling maintenance materials is to stockpile untreated sand-gravel or other mineral aggregate and to store asphalt oil in barrels adjacent to this supply. The materials are then mixed in the proper proportions by the use of small concrete mixers. This latter method has been abandoned on most of Kansas work and arrangements have been made on all new work to secure properly mixed materials from the project during construction.

The routine repairs and maintenance

methods on bituminous oil mats consist largely of two operations. The first and most important operation is to immediately patch small holes and correct any other surface defects that may appear. This is accomplished by cleaning out the loose material from the hole and replacing it with pre-mixed material from the stockpile. In some cases, a light application of road oil is sprayed over the defective portion of the surface which is immediately covered with the regular mineral aggregate as a blotter treatment. Other surface defects which appear in some bituminous mats are corrugations due to rolling or shoving. These may be caused by an excess of oil or moisture in the mat or moisture in the subgrade. When corrugations are caused by moisture in the subgrade, they are readily eliminated by removing the mat material and allowing the subgrade to dry. If it is apparent that moisture is present in the mat, remixing eliminates this condition and it can be relaid successfully. When tests show a slight excess of oil in the mat, the condition can be corrected by remixing and relaying. However, if tests or experience indicate that the excess of oil is so large that the corrugated condition cannot be corrected by remixing, it is necessary to mix additional mineral



*Roller built by the State Highway Department from old tractor wheels.
Shoulders should be rolled at regular intervals.*

aggregates with the existing material in order to obtain a stable mat.

The second operation which is of almost equal importance to surface maintenance is that of rolling and oiling the road shoulders. Maintenance forces are instructed to roll the shoulders of all bituminous mats at least once a week during the first two or three months that the road is open to traffic. Following this period, the shoulders are rolled whenever signs of raveling or "cutting up" under traffic appear. The balance of routine work on these highways is entirely similar to that used in the maintenance operations of any other type of road.

Major reconditioning of the mat surfaces is handled by a special outfit which has been provided for each of the six divisions of the State. The equipment consists of an 800 gallon pressure distributor, from two to four blade graders and the necessary heating equipment and other tools which would be required on a regular bituminous mat construction project.

The materials necessary to recondition the mat are determined by the materials department and are purchased, delivered and manipulated by the special division maintenance organization.

Shoulder Oiling

Another operation which is handled by division equipment is that of shoulder oiling. It has been the practice in Kan-

sas to oil all shoulders at least once each year, applying from .2 to .5 gallons of 65 oil per square yard over a width of from four to five feet. The oiling of these shoulders is an essential maintenance operation, the cost being relatively small, the saving in the reconditioning of shoulders more than offsetting the expenditure.

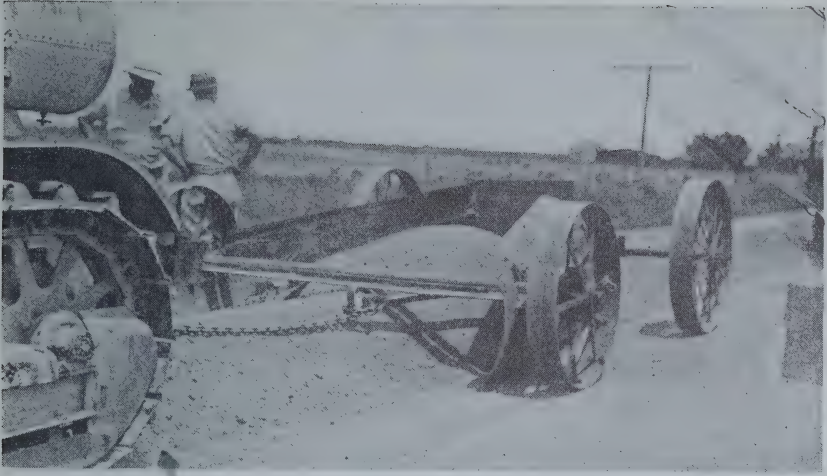
The practice of the Maintenance Department is to encourage the growth of grass shoulders to within about two feet of the edge of the bituminous mat. This makes a width of twenty-two feet for the mat with an additional two feet for each shoulder or a total of twenty-six feet under surface maintenance. The primary reason for the development of the sod shoulder is to increase the visibility for night driving.

Seal Treatment

The use of a seal treatment has been increased considerably during the latter part of 1932 and is also handled by the special division equipment. This treatment is used for the maintenance of those mats which show a tendency towards being too dry and have a rather open surface. The seal coat consists of the application of not to exceed .2 gallons per square yard of road oil or cutback asphalt, varying in grade according to the surface condition of the mat. The seal coat is covered with sand or chats before complete penetration has taken place, to

KANSAS BITUMINOUS MAT CONSTRUCTION IN 1932—RECAPITULATION

ITEM	DIVISION					
	1	2	3	4	5	6
Length (miles).....	38.139	99.931	33.825	127.545	166.687	52.121
Contract Price, per mile.....	\$2,582.70	\$2,439.61	\$2,192.67	\$2,273.44	\$2,268.63	\$2,154.31
Cubic Yards of Aggregate, per mile.....	493	527	491	560	528	452
Percent Passing 200 Mesh.....	14.3%	15.9%	13.5%	14.45%	11.7%	14.5%
Percent of Oil.....	14.0%	13.6%	11.7%	13.0%	11.5%	13.22%
Percent of Oil.....	5.58%	6.17%	5.20%	6.31%	5.79%	5.19%
Percent of Oil.....	5.22%	5.85%	4.95%	6.12%	4.99%	5.48%
Gallons per Square Yard.....	.633	.567	.476	.500	.451	.599
Gallons per Square Yard.....	.640	.783	.603	1.018	.767	.634
Total Gallons.....	1.273	1.350	1.079	1.518	1.201	1.233
Total Gallons.....	23,505	21,668	19,321	21,334	19,942	20,744
Aggregate.....	\$1,213.98	\$1,087.78	\$808.49	\$1,023.07	\$844.31	\$864.08
Oil.....	\$1,018.93	\$794.87	\$853.87	\$706.74	\$781.38	\$747.97
Manip.....	\$404.90	\$459.73	\$558.45	\$401.80	\$396.65	\$368.32
Engr. Cost.....	\$127.57	\$97.34	\$170.29	\$108.28	\$140.16	\$143.89
Total.....	\$2,765.38	\$2,439.72	\$2,391.10	\$2,239.89	\$2,162.50	\$2,124.26
Oil.....	.04455	.0354	.0485	.0318	.0390	.0353
Aggregate.....	2.14	2.062	1.37	1.97	1.434	1.43
Manip.....	6.30	6.61	6.60	7.53	7.65	6.14



Windrow Equalizer with adjustable gate at rear to control the volume of material in the windrow.

prevent the surface from becoming slippery and to allow the road to be open to traffic.

The handling of traffic on sealing and reconditioning work has presented some difficulties. The practice in Kansas is to provide detours wherever practicable, but where this is not done, signs are placed at each end of the work to warn the motorist of fresh oiling operations. Attempts have been made to treat only one-half of the road surface at a time, so that the traffic may use the other half while the oil is penetrating. Considerable difficulty has been experienced in keeping the traffic on the untreated portion, since in passing it is necessary to turn out on the fresh oil. It is impossible to slow the traffic down to a reasonable speed, and the practice of providing a suitable detour is highly recommended both for the good of the road and the protection of the automobiles using the highways.

Costs

A comparison of the maintenance costs for the fiscal year ending June 30, 1932, between sand-gravel surfaces and bituminous mats shows that there is a difference of \$63.90 per mile in favor of the latter type of construction. This difference in cost represents all items chargeable to maintenance except surface replacements. The replacement of surface

materials on sand-gravel sections represents a very substantial item in maintenance operations, but since bituminous mats are relatively new and have required very little reconditioning, no comparison should be made at this time of this item.

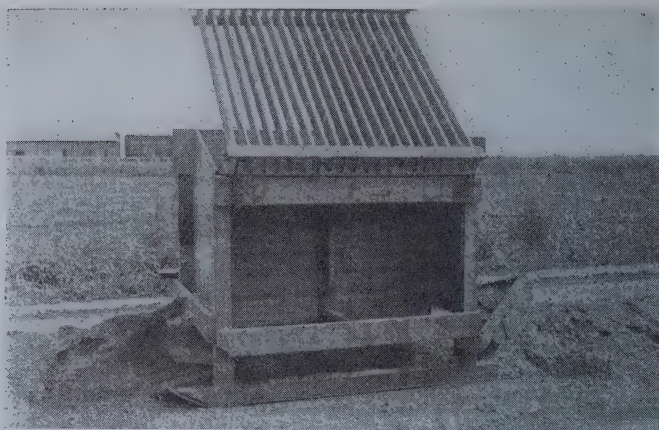
Conclusions

The conclusions and recommendations for future work which are based on the observations of the maintenance and construction of bituminous mats during 1931 and 1932 may be summarized in the following statements:

1. The portion of material retained on a $\frac{3}{8}$ " sieve should be increased to a minimum of twelve per cent, and the material passing the 200 mesh sieve, should be from 8 to 15 per cent.

2. The viscosity of the road oil should be kept near the center of the range specified unless otherwise requested by the Engineer, and *special investigation made to develop a test which will determine the relative resistance of road oil to weathering.*

3. Considerable attention should be devoted to surface treatments on existing mats which show signs of failure, rather than undertaking remixing processes in all cases. Where a mat is stable, a surface treatment will eliminate considerable expense, and it may



Device used by the Yant Construction Company to apply fines to the windrow measures the fines and covers the fines again with gravel.

be justifiable to use a coarsely graded aggregate with a cutback asphalt or road oil that will produce a more tenacious surface.

4. It is realized that heavier mats such as constructed in some of the other states are possibly more substantial and represent a higher type of construction than those which have been built in Kansas, but the objective of producing an excellent highway at a cost not greatly exceeding \$2,000 per mile has been attained.

5. This type of surfacing has been laid on soils varying from group A-1 through group A-7 when classified by means of the classification system as adopted by the Bureau of Public Roads. On several projects the soils came under group A-6 and group A-7, while on some projects in the western part of the state, the classification ranged from group A-2 to group A-4.

6. This type of surfacing has generally been used on routes having an average daily traffic count ranging from 500 to 1,500 vehicles, and in some special cases as high as 2,000 vehicles.

The acceptance of this type of construction by the general public is plainly indicated in the popularity that it has attained during the past two years. In 1930, there were 33 miles of bituminous mats on the State Highway System of Kansas, and on this date, there are 1,500 miles of this improved type. The building of this large mileage of bituminous mats has not interfered with the construction of higher type pavements where finances were available, but it has successfully replaced the choppy, dusty sand-gravel surface previously used for moderately heavy traffic in many sections of the state.

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ASPHALT PRIMING MATERIAL

CHARACTER AND USE

By

W. H. FOUSHEE, Jr.

Bituminous Engineer, North Carolina State Highway Commission

*(Paper presented at Tenth Annual Asphalt Paving Conference,
New Orleans, La., December 5-9, 1932)*

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Asphalt Priming Material—Character and Use

By W. H. FOUSHEE, JR.

Bituminous Engineer, North Carolina State Highway Commission

Necessity of a Prime Material

It has been found necessary to use a prime application in the construction of low cost pavements such as surface treatments and road mix types. It is generally understood that a prime material should partially fill the voids and tend to solidify the base in question, help reduce capillarity and at the same time serve as an adhering coat for the next application to follow. In most cases this is accomplished by applying a light material having sufficient penetrating qualities so that it may thoroughly coat the particles of the base in question. Different grades of materials are used in various states due to local conditions—generally a lighter material is used on denser surfaces and heavier materials on more porous surfaces.

Experience has taught that penetration is governed in most cases by the porosity of the base, grade of prime used and the types and characters of the surfaces to be treated. The engineer generally determines the consistency required to meet conditions so that maximum penetration is obtained.

When an inadequate amount of prime is used it very often leads to a failure and, therefore, maintenance becomes excessive. In most cases where an inadequate amount of prime is used the next application of bitumen will naturally act as an agent for the primer, filling some of the remaining voids, thereby reducing the quantity anticipated to hold the first application of stone, gravel, sand or blotter course. We do not believe that we can place too much stress on the proper laying of a prime coat. Careful inspection to see that every particle of the base is thoroughly covered, together with getting the proper amount of prime to accomplish this is very essential. This is one of the most important steps in surface treatment work since failure of the

prime very often leads to failure of the next treatment.

Characteristics That a Prime Material Should Possess

A prime material should possess satisfactory penetrating and bonding qualities, act as a seal and at the same time adhere to the next application of bitumen so as to form a homogeneous mat.

For a prime material we have found that asphalt base stock mixed with the proper solvent answers this purpose. We have also found that the asphalt is carried by the solvent to the extreme depth of the penetration which tends to strengthen the base and give it more flexibility as is desired in low cost pavements.

In order to prove this theory experimental tests were made by our Chemical Laboratory on various types of soils taken from active projects. The soils used in this work had an average clay content of thirty-three (33) per cent, and approximately seven (7) per cent of moisture. Care was taken to approximate the conditions as encountered on construction as nearly as possible. Uniform pressure was placed on test samples in accurately measured moulds and asphalt prime was applied at the approximate rate of one-third ($1/3$) of a gallon per square yard.

After six days the samples were examined and the penetration was found to be very uniform, having reached a depth of six-tenths (0.6) of an inch. Careful samples were taken from the top three-tenths (0.3) of an inch and from the bottom three-tenths (0.3) of an inch, and the bituminous content determined by extraction with CS_2 and by ignition. Deductions were made for the natural loss on ignition of the uncoated material. It was found that the average bituminous content was as follows:

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By Extraction with CS ₂ —Top layer	3.67%
By Extraction with CS ₂ —Bottom layer	3.31
By ignition —Top layer	3.33
By ignition —Bottom layer	2.98
Solid Asphalt left after removal of CS ₂ Solvent—Top layer....	2.63
Solid Asphalt left after removal of CS ₂ Solvent—Bottom layer..	2.37

From this data it is obvious that the asphalt is carried to the full depth of the prime penetration.

Specifications for Asphalt Prime

AC-1 ASPHALT PRIME

The base shall be a straight run product, homogeneous, free from moisture, and shall conform to the following specifications:

	Min.	Max.
1. Specific Gravity @ 60°F.	1.00	1.05
2. Flash (Cleveland Open Cup) °F.	450	
3. Softening Point (Ball & Ring) °F.	115	125
4. Penetration 77°F. 100 gr. 5"	85	100
5. Volatility—50 gr.—5 hr.—325°F. (per cent) ...		0.5
6. Penetration of Residue—77°F.	65	
7. Ductility at 77°F.—CMS	100	
8. Solubility in Carbon Bi-Sulphide (per cent)	99.5	

The solvent shall be a petroleum distillate which shall conform to the following specifications:

	Min.	Max.
Initial Boiling Point °F.	320	350
Per cent off @ 410°F.	10.0	
End Point °F.		540

The finished product shall be made from the above ingredients in such proportions as to conform to the following specifications:

	Min.	Max.
1. Specific Gravity @ 60°F.	.90	
2. Viscosity @ 77°F. (Furol)	50	80
3. Flash Point (Cleveland Open Cup) °F.	100	
4. Per cent Asphalt @ 100 Penetration	50	
5. Soluble in Carbon Bi-Sulphide	99.5	
6. Distillation—Per cent by Volume:		
Total distillate 0 to 428°F.	5	20
Total distillate 0 to 680°F.	35	50
7. Penetration of Residue @ 77°F. 100 gr. (seconds) ..	5	250

Method of Distillation: A.S.T.M. D-20-30 except tagliabue high range distillation thermometer is placed ¼ inch from bottom of flask and the residue is removed from the flask immediately after the distillation is completed.

It was found that we needed in most cases a primer of heavier body than our original specifications, consequently we incorporated an alternate specification as follows:

AC-1 ASPHALT PRIME (ALTERNATE)

The base shall be a straight run product, homogeneous, free from moisture, and shall conform to the following specifications:

	Min.	Max.
1. Specific Gravity @ 60°F.	1.00	1.05
2. Flash (Cleveland Open Cup) °F.	450	
3. Softening Point (Ball & Ring) °F.	115	125
4. Penetration 77°F. 100 gr. 5"	85	100
5. Volatility—50 gr.—5 hr.—325°F. (per cent) ...		0.5
6. Penetration of Residue—77°F.	65	
7. Ductility at 77°F.—CMS	100	
8. Solubility in Carbon Bi-Sulphide (per cent)	99.5	

The solvent shall be a petroleum distillate which shall conform to the following

	Min.	Max.
Initial Boiling Point °F.	320	350
Per cent off @ 410°F.	10.0	
End Point °F.		540

The finished product shall be made from the above ingredients in such proportions as to conform to the following specifications:

	Min.	Max.
1. Specific Gravity @ 60°F.	.90	
2. Viscosity @ 77°F. (Furol)	100	125
3. Flash Point (Cleveland Open Cup) °F.	100	
4. Per cent Asphalt @ 100 Penetration	50	
5. Soluble in Carbon Bi-Sulphide	99.5	
6. Distillation—Per cent by Volume:		
Total distillate 0 to 428°F.	5	20
Total distillate 0 to 680°F.	35	50
7. Penetration of Residue @ 77°F. 100 gr. (seconds)	5	250

Method of Distillation: A.S.T.M. D-20-30 except tagliabue high range distillation thermometer is placed $\frac{1}{4}$ inch from bottom of flask and the residue is removed from the flask immediately after the distillation is completed.

Types of Surfaces Primed with Asphalt in North Carolina

Priming and Treating Traffic-bound Macadam with Asphalt

Asphalt prime was first tried in North Carolina on a trafficbound macadam section of road in the western part of the State. This type of road consists of layers of stone and dust compacted by traffic during construction, having enough dust to partially fill the voids in the stone. This finished surface just before treatment generally has an appearance of loose stone and dust of from one-quarter ($\frac{1}{4}$) to one (1) inch in thickness on the surface, the underlying part having bonded under traffic.

The problem here was to get maximum penetration of the bitumen, together with sufficient bonding qualities to solidify the loose stone and dust and at the same time get the proper keying effect to the underlying base. Additional stone was added to completely cover the bare spots on the existing macadam.

First Application of Prime

An application of asphalt prime was then applied at the rate of from thirty-five hundredths (0.35) to four-tenths



North Carolina Highway.
Primed base with thin asphalt wearing course. (Showing cut section.)

(0.4) of a gallon per square yard by means of a pressure distributor to the full width of the surfacing. The prime was not heated to more than one hundred and thirty (130) degrees Fahrenheit and was not applied at a temperature of less than one hundred (100) degrees Fahrenheit.

Mixing Prime with Stone and Dust

This first application of prime was thoroughly mixed with the loose stone and dust by means of blade graders and long base multiple blade maintainers until all the stone and dust in the judgment of the Engineer had been coated with bitumen and had begun to get somewhat viscous. This mixed stone and dust was then windrowed to the sides. We might add here that different methods of windrowing were used. Sometimes it was placed on the quarter point of the macadam and at other times on the shoulder. This, of course, depended on the type of shoulder used in the construction of the macadam. We tried to manipulate it so that the mixed material would not become contaminated with any shoulder material unless it was suitable to be mixed with the asphalt prime.

Second Application of Prime

After the mixed stone and dust had been windrowed a second application of asphalt primer was placed on the underlying base at the rate of from three-

tenths (0.3) to four-tenths (0.4) of a gallon per square yard and allowed to penetrate.

Spreading Mixed Material

After the second application of prime had been allowed to penetrate, the previously windrowed mixed stone and dust was uniformly spread to the section shown on plans by means of blade graders or long base multiple blade maintainers. No roller was used on this application due to the fact that we believed that traffic would have a tendency to give it more uniform compaction. Traffic was allowed to use the road in this condition for several days or until it had thoroughly solidified.

Spreading and Smoothing Coarse Aggregate

As soon as the mix had thoroughly set and solidified an application of one (1) inch stone was uniformly spread at the rate of from forty (40) to forty-five (45) pounds per square yard.

Application of Binder Material and Mixing with Coarse Aggregate

After the stone had been satisfactorily smoothed and thoroughly dried out an application of asphalt cut-back having a base of eighty-five (85) to one hundred (100) penetration and a Furol viscosity



*North Carolina Highway.
Primed base with thin asphalt wearing course.*

at 122° F. of from 210 to 270 was applied at the rate of from forty-five hundredths (0.45) to five-tenths (0.5) of a gallon per square yard. This application was then thoroughly mixed with the stone using the same equipment as I have mentioned in the mixing of the prime coat. This mixing was carried on until the asphalt began to set to the stone, at which time it was smoothed out and rolled with a 5-ton roller. We allowed traffic to use this road for about three months, at which time a seal coat was applied using asphalt cut-back having a base of eighty-five (85) to one hundred (100) penetration and a Furol viscosity at 200° F. of from 75 to 125 and eighteen (18) to twenty-five (25) pounds of $\frac{3}{4}$ " stone as cover. No attempt was made to mix this seal. At the present time this road is in very good condition showing no signs of failure whatsoever.

Priming and Treating Soil and Clay Gravel Roads with Asphalt

Our experiments had been satisfactory with the use of asphalt prime on traffic-bound macadam so it was decided to try this material on some of our soil or clay gravel roads.

Application of the Prime Coat of Asphalt on Clay Gravel Base

The road selected for this experiment was clay gravel surfacing, having a clay content of approximately thirty-one (31) per cent. The existing surface was thoroughly cleaned of loose particles and dust for the entire width of the treatment by sweeping with a revolving broom supplemented with hand brooms. After the surface was thoroughly cleaned and showed no signs of free moisture an application of asphalt prime was applied at the rate of one-third ($1/3$) of a gallon per square yard. I noticed in particular the penetrating qualities of the asphalt—within two hours after the first load had been poured a penetration of from one-eighth ($1/8$) to one-half ($1/2$) of an inch was encountered. The prime was allowed to dry in from three (3) to forty-eight (48) hours, depending on the character of soils and weather conditions. Generally we let the prime dry in about

five (5) hours at which time we could drive over it without same picking up. On this phase of the work we find that the asphalt prime is advantageous in not slowing up the next application. The prime was followed by an application of heavy asphalt cut-back having a base of eighty-five (85) to one hundred (100) penetration and a Furol viscosity at 200° F. of from 220 to 280. This asphalt was followed with an application of local washed sand gravel ranging in size from one (1) inch down, at the rate of from thirty-five (35) to forty (40) pounds to the square yard. After the application of washed gravel had been uniformly spread and dragged with a broom drag it was thoroughly rolled with a 5-ton roller until all the gravel had embedded in the asphalt. Traffic was allowed on this project within two or three days after it had been completed. The broom drag was kept on the sections that had not entirely set to keep the gravel cover uniformly distributed. At the present time this road is in very good condition and we do not anticipate any serious trouble—what effect the winter months will have on it—we are at present unable to say.

Since the first experiment on a clay gravel base we have tried an asphalt prime on various types of soil roads, and the results have been satisfactory.

Approximate Cost of Prime

The cost of doing this class of work depends largely on the haul limits and prices of materials which vary in different localities.

We have recently awarded contracts on several projects for straight surface treatment on soil and gravel surfacing. The bids received averaged eighteen and one-half (18.5) cents per square yard. The specifications called for one-third ($1/3$) of a gallon of asphalt prime. This was followed by four-tenths (0.4) of a gallon of straight run asphalt covered with thirty-eight (38) pounds of one (1) inch to one-quarter ($1/4$) inch stone. In two to six months a seal coat was applied using one-third ($1/3$) of a gallon of asphalt cut-back covered with twenty-two (22) pounds of three-quarter ($3/4$) inch to one-quarter ($1/4$) inch stone. A 5-ton roller was used on both applica-

ASPHALT PAVING CONFERENCE, 1932

tions of stone. The specifications also called for a thirty-day maintenance period.

The cost for applying asphalt prime averages around two and one-half (2.5) to three (3) cents per square yard. This includes initial cost of heating, hauling and applying or fifteen (15) to eighteen (18) per cent of the total treatment. The average cost for applying the first application of straight run asphalt averages around two and eight-tenths (2.8) cents to three and one-half (3.5) cents per square yard. Stone cover, initial cost of hauling, spreading, brooming and rolling and incidentals average from six and one-half (6.5) cents to seven and one-half (7.5) cents per square yard. The seal coat using asphalt cut-back and three-quarter ($\frac{3}{4}$) inch stone as a cover aver-

ages six and one-half (6.5) cents to eight (8) cents per square yard.

On the treatment of trafficbound macadam we have recently received bids on three different projects which averaged twenty-seven (27) cents per square yard. These bids were much higher due to the increased quantities which are necessary in a treatment of this nature.

In conclusion it has been my desire to outline to you in brief our experience with an asphalt prime material in North Carolina together with our methods of construction. We are pleased to have this opportunity to present our experiences and hope that the information contained herein will be helpful to you in the laying of surface treatment in the future.

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Asphalt as a Resurfacing Medium for Pavements

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The scope of this paper is rather broad making it difficult to completely cover it within any reasonable period of time, but as a result of over twenty years' experience with the State of New York and with the Bureau of Public Roads at Washington, I am convinced that one of the best methods of research is to study the history of the performance of existing highways. I have taken the liberty, therefore, of assembling what I will call historical data covering several *general types* of resurfacing commonly used in New York State.

In order to make a proper analysis of any historical data, it is necessary to be reasonably familiar with the background from which the data is obtained. Highway history in New York State began, in a limited way, about 1905 and proceeded at a limited pace until about 1914. The latter date marked the advent of cement concrete pavement construction and the advent of a greater construction program, culminating in 1931 when there were constructed and reconstructed about 1,000 miles of high type pavement, at a cost of approximately \$50,000,000. This is truly a tremendous industry and research, properly guided, is not only important but imperative. Furthermore, good highway practice cannot be properly determined by an individual but must be determined by a consensus of opinion of properly qualified highway administrators. Hence the importance of meetings of the character of this, the Tenth Annual Asphalt Paving Conference, where such administrators are gathered and from which the public must and will receive innumerable benefits.

Factors Affecting Choice of Pavement Types

The one unflinching economic test for any pavement is to determine whether or not the benefits derived are commensurate with the cost. The selection, therefore, of

a proper economic type of pavement must, in each case, consider availability of material as it affects the cost. Let us assume that we are in a territory abundantly provided with clean, sharp sand suitable for use in Type 2 (Modified Topeka) pavement. This would probably be the determining factor in arriving at the particular type of asphaltic surface to be constructed. If it were in a territory with an abundance of suitable stone available commercially or which could be easily crushed upon the site of the work, it is probable that we would select a so-called stone mix (M.M., Type 3) for use in that particular locality. If both sand and stone were available, it is probable that a so-called composite mix (Asphaltic Concrete) would be selected as the most economical type.

New York State has an abundance of excellent sand and stone aggregate in the northeastern and southeastern areas. In the central, southern and western portions it has a limited amount of sand, stone and gravel of fair to good quality, the use of which is economically justified from the standpoint of its availability. Present types of pavement, therefore, have been generally determined by the aggregates available, with due regard to the thermal ranges from 100° Fahrenheit to 30° below zero; to long periods of alternate freezing and thawing; to subgrade soils varying between finely divided sand and water-bearing clay; to amount of traffic both in weight and in number of vehicles, as well as rain, snow and ice for long periods. These factors, together with the practice of snow removal in winter and density of population in the State (12,588,066 in 1930), practically demand the best and most expensive types of construction. Our standard specifications and the limiting values adopted for acceptable aggregates, therefore, have been largely determined by the above factors.

Classification of New York State Mileage

In the State, outside of cities and incorporated villages, there are approximately 80,000 miles of public highways.

Of this total approximately 14,000 miles are on the State System and on January 1, 1932, there had been improved approximately 11,689 miles of the following types:

Block Pavements (Brick, Asphalt, Wood and Stone)	213.32
Concrete Pavements (All classes and all types)	5,649.25
Mixing Method (Various types on conc. and mac. bases)	709.02
Dual Types (Concrete and Macadam Bases)	3,438.01
Miscellaneous Types (Waterbound and Gravel)	1,534.50
Total	11,688.75

Twenty-five years ago there were practically no pavements in the State, while at the present time there are approximately 12,000 miles of improved highway on the State System. New construction has proceeded at the average rate of 480 miles per year and more recently our reconstruction has proceeded at the rate of about 400 miles per year. This amount of annual reconstruction has been partly due to complete or partial failure of old pavements caused by a tremendous increase in the volume, weight and speed of motor vehicles. Motor vehicle registration has increased from 234,000 in 1915 to 2,361,978 in 1932. Truck traffic, both in weight and volume, has increased, at least in a proportionate amount, and obviously the older highways are inadequate. Most of the pavements built up to 1922 were not over 16 feet wide while at present we have at least 1,000 miles of three-lane and four-lane pavement. Present practice is to build 20 feet of pavement for two lanes, 30 feet for three lanes and 40-44 feet for four lanes. Present design practice is to provide 800-foot sight distance, 1,500 feet minimum of radius of curve, 5 per cent grades on main arteries and 600-foot sight distance, 800 feet minimum radius of curves and 7 per cent grades on the secondary system. These general design requirements are necessary to provide safe, rapid and economical transportation and they partly account for the necessity of reconstructing 400-450 miles per year.

Re-surfacing vs. Re-construction

The necessity of obtaining added width, added strength and greater sight distance, especially during the past ten years, presented a very difficult economic

problem and one of large magnitude, namely, what portion of our older pavements could be used in whole or in part and what portion of our older pavements should be disregarded or abandoned. Many of the older pavements were structurally sound and from that standpoint would have served for some years to come but they contained alignment and grades suitable only for stage-coach transportation. The mileage of pavement with improper alignment and inadequate width is so great that we are firmly convinced of the absolute necessity of providing sight distance, alignment and grade, on all future construction, which will be adequate for at least twenty-five years and perhaps longer. We apply the same principles of design wherever in reconstruction we abandon or disregard the old locations of pavement and improper alignment. These same characteristics result in a natural distinction between the term "Resurfacing" and the term "Reconstruction." The term "Resurfacing" as used in this paper includes those cases where sight distance, alignment and grade of the old pavement are reasonably adequate, requiring only minor relocations, but the pavement has partially failed or is too weak to support traffic or is so rough as to be uncomfortable and dangerous to traffic. While not germane to this paper, I consider "Reconstruction" generally to include those cases where a new pavement is constructed but only a small part of the old pavement is utilized by the new alignment and new grade.

The term "Resurfacing" as used in this State consists of the addition of a substantial top course to an existing pavement. Where thus applied, the top course must have sufficient depth and stability

to avoid being moved or displaced by traffic. If sufficient depth is not provided and the pavement starts to shove, the remedy is more expensive than the first cost. Where resurfacing is applied to any old pavement, a suitable bond should be obtained by scarifying or by applying a light coat of asphalt to the old pavement. The latter method should be avoided if there are any fat spots on the old pavement. Fat spots should be removed from any pavement prior to the addition of top course.

For resurfacing concrete pavement we generally use a compacted depth of 2 inches where Cold Mix M.M., Type 3 is used and 3 inches where Hot Mix M.M., Type 1 or Type 2 is used. The top course may be constructed in one or two courses but the usual practice in New York State is to place it in two separate courses. The bottom or base course contains larger aggregate and the top or finishing course consists mostly of the finer aggregate down to and including sand in hot mix. The bottom or base course is used primarily for leveling up, as well as the addition of a certain amount of strength. In fact, all leveling up should be accomplished with the bottom course as it is practically impossible to take out irregularities in the top course alone.

Not being familiar with practice in other States, I will mention two classes of work performed in our State, known as Light Surface and Heavy Surface Treatment. For some years past we have applied Light Surface Treatment amounting to about 2,000 miles per year. It consists of an application of about one-quarter gallon of bituminous material and about 50 tons to the mile of No. 1 or No. 2 stone at an average cost of \$465 per mile. However, we do not term this class of work "Resurfacing" as it does not add strength or depth to the old pavement but requires frequent applications to protect the pavement, the expenditure is a constantly recurring one and we, therefore, class it as Maintenance. For the past six years we have applied heavy Surface Treatment on an average of about thirty miles per year at an average cost of about \$1,600 per mile. This consists of a dual application of asphalt, using a cover of about 120 tons of stone per mile, thoroughly rolled and then open to traffic. We find this quite an ef-

fective method of prolonging the life of some of our concrete pavements, especially in those cases where the pavement has sufficient depth but gives us trouble by scaling or ravelling. The life of this treatment is principally determined by the volume of traffic it is called upon to carry. It wears down considerably with lapse of time and then requires another application of a similar treatment. In snow country, where snow removal is practiced by the counties, this kind of a treatment may have to be renewed as frequently as every other year or every third year at least on account of the use of chains on tires. It builds up a mat about 1 inch thick and adds some strength to the pavement. Its use is justified as it provides a wearing surface, impervious to moisture, and postpones reconstruction thus conserving public funds.

Asphalt for Re-surfacing

Asphalt is peculiarly adapted to the work of resurfacing, especially in the so-called mixed types of macadam pavement. This is partly for the reason that it may be used hot or cold; it may be used in a leveling-up course varying in depth from $\frac{1}{2}$ inch to 3 inches; strength of pavement may be increased by adding additional courses as desired; and its life differs from that of mortars in that its youth may be renewed by intelligent treatment. If we consider asphalt as having a cementing property, performing similar functions to Portland cement in concrete pavement, it would seem unnecessary to dwell at great length on its different kinds and properties. The 1932 specifications of New York State include ten different items of asphaltic materials and five different items of Asphalt Emulsions. Specification limits for the different types of asphalt cover its use, when heated, in Asphaltic Concrete—M.M., Type 1, Penetration Macadam, Modified Topeka—M.M., Type 2, Surface Treatment and Brick Filler. They also contain limiting values for asphalts used cold in M.M., Type 3, cold application for surface treatment of shoulders, cold application for surface treatment of pavement, cold application for heavy surface treatment of pavement; road-mix and for patching or cold patch work. The five types of Emulsion embrace Type 1 for

patching, Type 2—a non-freezing patching material, Type 3 for surface treatment or penetration, Type 4 for curing concrete and Type 5 for Road-mix.

As I have previously intimated in this paper, the aggregates available for the construction of pavements (particularly concrete) not only determine the type but later events have proven that aggregates have partly determined the life of concrete pavement. We now have approximately 5,650 miles of concrete pavement on the State System, which is a little over 50 per cent of the total mileage as of January 1, 1932. The problem, therefore, of resurfacing or reconstructing the older concrete pavements is one of first magnitude and the time when they should be resurfaced or reconstructed is of extreme importance. Improper decisions on this vital point may result in a considerable waste of funds and such decisions should not be entrusted to subordinates. While I have indicated above that the character of aggregates has partly determined the useful life of concrete pavements, the type of design of older pavements is also an important factor. Many of our older pavements are $4\frac{3}{4}$ "- $6\frac{3}{4}$ "- $4\frac{3}{4}$ " in depth with a parabolic crown constructed upon a flat subgrade. They are thin at the edge and thick at the center and were constructed monolithic for the full width of pavement. These principles of design are diametrically opposite those of present-day practice and this edge weakness may account for some of our partial failures. In any event the exact time for reconstruction constitutes a study by itself and warrants thorough investigation by all highway administrators.

As an interesting example of the use of hot mix for resurfacing concrete pavement, I have selected four typical highways which are among the first jobs of this character resurfaced by the State. For convenience I will designate them as A, B, C and D. Three of these, A, B and C, are located on a heavily traveled route from Buffalo to the Pennsylvania State Line. The traffic on this route is about 6,000 vehicles in twelve hours which we consider a heavily traveled road.

Road A (S. H. 5600) is 2.11 miles long, Road B (S. H. 5634) is 5.28 miles, and Road C (S. H. 5546) is 4.5

miles long. They adjoin each other, forming a continuous stretch extending north-erly from the south Erie County Line, but were constructed at different times. The old pavement was 16 feet in width. Soil conditions were very difficult and unsatisfactory. From a considerable knowledge of general conditions throughout New York State, I can say that the sub-grade conditions on these three projects were as bad as any encountered in the State. It was a stiff clay nature which holds surface water and provides an unstable base. At the time of reconstruction, each of these pavements was quite rough, somewhat broken up, with considerable evidence of scale and some disintegration. In fact there was considerable doubt in the minds of practically all of the administrators in the Department, except myself, as to the adequacy of a 3-inch mixed top applied to these pavements to satisfactorily carry the heavy traffic which was expected on this highway.

Road A (S. H. 5600)

[See line drawing, page 12]

The original concrete pavement was constructed in 1916 of a 1-1½-3 mix, 5"-7"-5" in depth, 16 feet wide with parabolic crown, treated wood expansion joints 33 feet apart, on a flat subgrade and without longitudinal center joint.

The highway was reconstructed in 1923 by the addition of a 3-inch Modified Topeka Top Course (M.M., Type 2) consisting of a 1½-inch leveling course and 1½-inch top course over the existing pavement. At the time of reconstruction the old pavement was badly scaled and badly cracked but with little displacement of broken concrete. It had a dead sound when struck with a hammer. Also, it had been extensively patched.

The typical section shows the design of the completed pavement, the cross hatched portion showing the original pavement. The shoulder is only 3' 6" wide from the outside of the edging, but this was done in order to keep the earth work to a minimum. A concrete edging 1' 6" wide and 10" deep, with metal reinforcement near the bottom was constructed on each side of the old pavement. These edgings increased the traveled way from 16 feet to 19 feet, served as a form for placing and finishing pavement and,

due to the color contrast, made excellent pavement markers on the outside edge of pavement.

The resurfacing contract was 2.11 miles long; it required four months to complete; it embraced 20,400 square yards of macadam top and it was necessary to replace approximately 570 square yards of the old concrete. All broken concrete of less than 4 square feet was removed, the holes squared up and replaced with new concrete and the poorest concrete was also removed and replaced. The replacement of concrete was $2\frac{1}{2}$ per cent of the total area of the old pavement and not all of the poor concrete was removed by any means.

The asphalt in the top course averaged $8\frac{1}{2}$ per cent. Analysis of the mineral aggregate in the top course is as follows:

7%	passed 200 screen
17%	" 80 "
26%	" 40 "
30%	" 10 "
40%	" 4 "
10%	" 2 "

The average weight per square yard of the top course was 147 pounds ($1\frac{1}{2}$ " thick).

The analysis of the bottom course is as follows: $4\frac{1}{2}$ per cent of asphalt, 10 per cent of sand, and the balance of stone of approximately $\frac{3}{4}$ " in size. The bottom course weighed 149 pounds per square yard which includes some leveling.

The cost of the entire project, including the added three feet of concrete edging, was \$55,000, or an average of about \$28,000 per mile. The cost of macadam only was \$1.54 per square yard.

There are four principal objections to this typical section:

1. The edging, flush with the finished pavement, holds water along the edge of the asphalt at all low spots in grade. We later cut holes through this edging, with an air compressor, to serve as weeps so that water could be drained away from the asphalt.
2. It was later necessary to add a third lane of concrete pavement and there are now too many longitudinal joints showing through the top of the pavement, which re-

quire constant maintenance to prevent water from seeping in the joints.

3. The top of both edging scaled badly and it was necessary to surface treat it, thus destroying the white strip for guiding traffic.
4. Heavy traffic slowly displaced the edging in places as the line of wheel travel was near the construction joint. This action was foreseen but we thought the 18-inch edging had enough stability to keep it in place.

There are also several precautions which should be taken under the general heading "Details of Construction":

1. All old bituminous mat should be removed and the old pavement should be thoroughly cleaned. We covered this feature by inserting an item in the contract identified as "Cleaning Old Pavement" and paid for it by the square yard.
2. While the transverse joints on this old pavement were of treated wood, later pavements used bituminous material (premoulded joints). At least one inch of the top of the old premoulded joints should be removed prior to placing the binder course, otherwise expansion of the concrete forces the bituminous material to the top and creates humps in the finished asphalt pavement.
3. While the typical section shows a vertical inside face of the edging, we actually removed a little of the subgrade under the edge of the old pavement and permitted the concrete to flow under the edge of the old pavement, thereby giving it some added support.

The pavement today is in fair shape. There are some depressions in the old concrete base but the concrete has not been displaced and it has been leveled up with M.M., Type 3. In the construction of the top course some stone dust was used in the mix in order to reduce the amount of expensive bagged mineral filler. In my opinion, this was a mistake as it prevented rigid control of the mix and has resulted in a few fat and a few dry spots

in the surface of the pavement. On all similar work since that time, the substitution of stone dust for the regular mineral filler has not been permitted.

Attached, as a supplement to this paper, there is shown in tabular form the maintenance costs on pavement only since the original construction in 1916 up to and including the year 1931, together with a traffic census consisting of a 12-hour count from the year 1922 to 1931. Maintenance charges in the years 1930 and 1931 include maintenance on an eleven-foot strip of concrete, 1.3 miles long, which was built in 1928 in order to widen the pavement to thirty feet. The drop in traffic census from 6,546 in 1930 to 3,099 in 1931 is explained by the fact that a parallel route into Buffalo was completed in the latter year and it somewhat relieved traffic congestion on this highway.

Road B (S. H. 5634)

[See line drawing, page 12]

The original concrete pavement was constructed in 1920 of 1-1½-3 mix and 5½"7½"-5½" in depth. The pavement was sixteen feet in width, the subsoil was clay quite similar to that which existed on S. H. 5600 described above.

The pavement was reconstructed in 1925 by adding 3 inches of Modified Topeka Top course consisting of 1½-inch leveling course and 1½-inch binder course with 18-inch concrete headers on each side. The subgrade on this highway was a pure clay holding considerable moisture, the pavement was very rough, was somewhat broken up and it was covered with considerable scale at the time of reconstruction.

The typical section of pavement is the same as Road A except the edging is 12 inches instead of 10 inches deep. The shoulders are 7 feet to break line and 3 feet to inside of ditch line. This required removal of much more excavation than on Road "A." This contract was 5.28 miles long; the total width of pavement, including edging, was 19 feet. It embraced 50,000 square yards of Topeka top and required five months to reconstruct. It was necessary to replace approximately 1,520 square yards of the old pavement with new concrete foundation which amounted to about 3 per cent of the total surface area of the old pavement.

The asphalt in the top course averaged 8½ per cent. Analysis of the min-



Road B—No. 5634.
General view of completed pavement. October, 1932.

eral aggregate in the top course is as follows:

8%	passed 200 screen	
22%	"	80 "
32%	"	40 "
15%	"	10 "
10%	"	4 "
13%	"	2 "

The weight per square yard of top course was 150 pounds ($1\frac{1}{2}$ inches thick).

The asphalt in the bottom course averaged $4\frac{1}{2}$ per cent with about 5 per cent of sand and the balance of $\frac{3}{4}$ -inch stone. The bottom course weighed 150 pounds per square yard which included leveling.

The total cost of the contract was \$180,000 or \$34,000 per mile (including new shoulders) and the macadam top was 3 inches thick including leveling, and cost \$1.33 per square yard.

The pavement today is in very good condition and the concrete foundation failures since resurfacing are practically negligible. This is probably due to the greater depth of old concrete than in the case of Road A. S. H. 5600, described above. The asphalt mix used is satisfactory and no change is recommended.

Traffic became so badly congested that the pavement has recently been widened to 30 feet by the construction of an 11-foot strip of concrete along one side throughout its entire distance. Attached herewith is a tabulation of maintenance costs per mile of pavement only and a traffic census from 1922 to 1931 inclusive.

Road C (S. H. 5546)

This pavement was originally constructed in 1915 of 1- $1\frac{1}{2}$ -3 mix, 6"-8"-6" in depth, 16 feet in width. It was reconstructed with Type 2 (Modified Topeka) in 1926-27. The typical section varies somewhat from the previous ones due to the addition of a third lane of concrete pavement. Having in mind this ultimate width of 30 feet, you will note that on the portion between the old pavement and the new 10-foot lane we widened the so-called Black Top by placing it on a newly constructed concrete foundation, 4 feet in width. This is better construction and, no doubt, would have been adopted on Roads A

and B had we anticipated the necessity of adding another lane of pavement at the time the original pavement was resurfaced. You will note from the typical section that there is only one exposed longitudinal joint where the black top contacts with the new concrete pavement.

This contract was 4.5 miles in length: it provided for the construction of about 46,000 square yards of M.M., Type 3; total cost of project was \$260,000, which equals approximately \$58,000 per mile. The per square yard cost of the Type 2 pavement was approximately \$1.28. The details of construction were practically the same and the materials were practically the same as in Road B. In this project it was necessary to replace 3,650 square yards of the old pavement, which amounts to about 10 per cent of the total area. This is noticeably greater than on the other two projects and it is probably accounted for by the fact that the old pavement remained in use from 1915 to 1926, a period of eleven years.

The resurfaced pavement today is in very good condition. No foundation failures have developed and the macadam has proven to be an economic method of salvaging the old pavement.

Road D (C. H. 1380-A—C. H. 9028)

In order to show the adaptability of asphalt and asphaltic types of pavement to a problem requiring the resurfacing and widening of an existing 1-lane concrete pavement, I have selected a location on Route 17 in Chautauqua County along the south shore of Chautauqua Lake. This pavement was originally constructed as 9 feet in width by the county in 1920. On account of the tremendous increase in traffic, it became necessary to take this road over on to the State System and widen it to at least 2 lanes. To this extent, the problem was slightly different than the one encountered in Roads A, B and C, discussed above.

The old concrete had been in use about seven years. It was originally constructed 6 inches in depth and it showed some signs of partial failure. There was no economic reason for building a pavement of greater strength on one-half than on the other, yet there was some doubt as to the ability of the old 6-inch concrete pavement, reinforced by addition of 3

inches of M.M., Type 2, to carry the expected increase in traffic. On the other hand, if new concrete, 5-inch minimum depth, was added to the old concrete, it would have been necessary to construct the new half width 11 inches thick in order to obtain a properly balanced design. This would also have undoubtedly increased the cost of reconstruction. It was finally decided to construct a new concrete base (Item 46-Concrete Foundation for Pavement) adjacent to the existing pavement wherever the alignment and grade were satisfactory. This new base was constructed 9 feet in width with a uniform depth of 6 inches, a 1-2½-5 mix and without transverse joints. You will note that I did not use the so-called edging in this construction principally on account of the objections enumerated under Roads A, B and C. While the omission of the edging resulted in a pavement only 18 feet in width, I can say that it has given reasonable satisfaction from that standpoint and we have had no particular trouble due to the omission of transverse joints in the pavement base. The traffic count on this highway was in the neighborhood of 2,500 vehicles in 12 hours, which is less than half the amount of the three examples discussed above.

This project was reconstructed in 1927-28 with M.M., Type 2 (Modified Topeka) hot mix asphalt macadam consisting of a 1½-inch leveling course of binder and 2-1½-inch top course. The project was 10.76 miles in length; it contained 116,500 square yards of macadam and it was necessary to replace 2,940 square yards of the old concrete pavement, which is 5 per cent of the original area. The asphalt in the top course averaged 8.7 per cent and in the bottom course it averaged 4.5 per cent.

Analysis of the aggregate in the top course is as follows:

7%	passed	200	screen
10%	"	80	"
58%	"	40	"
12%	"	10	"
5%	"	4	"
8%	"	2	"

The bottom course consisted of ¾-inch stone with about 12 per cent sand. The weight per square yard of the top course

was approximately 145 pounds (1½ inches thick) and the bottom course was approximately 161 pounds. The total cost of the project was \$327,600 or an average cost of \$30,450. The cost of macadam was \$1.08 per square yard (3-inch depth and leveling). The pavement today is in very good condition and requires very little pavement maintenance. The longitudinal center joint caused a crack through the top but it is not unsightly and can easily be poured with asphalt at very little cost.

In order to complete the pavement during the first construction season the contractor, at our request, worked a day shift and a night shift. The night shift placed the bottom or binder course under artificial lighting. The shadows cast by the lights really accentuated the depressions in pavement in the same manner that automobile headlights show up and magnify rough spots in night driving. As a result of this peculiar feature the bottom course was smooth as a billiard table with corresponding effect on the top courses. Also, I believe there was no added cost to the contractor as it released an expensive plant for the following season's work in another location.

Attached as a supplement is a tabulation showing the maintenance cost on pavement only since the time of resurfacing, together with the traffic census (12-hour day count) from 1929 to 1931 inclusive.

As an example of the use of cold mix M.M., Type 3, I have selected several of the older types as follows:

Road E (C. H. 1066)

This highway was originally constructed in 1915-16 as a 1-1½-3 cement concrete pavement, 6"-8"-6" in depth, 16 feet wide, parabolic crown, flat subgrade, on a clay and clay loam subsoil. It was resurfaced in 1928-29 by widening the old pavement with 4 feet of concrete, 1-2½-5 mix and 7 inches thick. It was covered, the entire width, with 1½-inch bottom and ½-inch top course of bituminous macadam, M.M., Type 3 (Referred to as M.M., Type 4).

The mix was as follows:

	Stone	Asphalt	Hydrated Lime	Mineral Filler
Bottom Course . . .	91.9%	4.6%	0.5%	3%
Top Course	86.5%	5.0%	0.5%	8%

There were 11 pints of liquefier used per ton of mix in the bottom course and 2 gallons per ton of mix in the top course. All of the aggregate in the bottom course was retained on a $\frac{3}{8}$ -inch mesh and passed a 2-inch circular screen. The aggregate in the top course was retained on a No. 8 mesh and passed a $\frac{5}{8}$ -inch circular screen. The mineral filler consisted of stone screenings, 90 per cent of which passed the No. 8 screen. The project was 5.25 miles in length; contained 62,000 square yards of pavement; total cost was \$176,584.84, which is an average cost per mile of \$33,600. The cost of the Black Top only was \$1.44 per square yard, which is equivalent to \$10.75 per ton. One ton of black mix covered 7.45 square yards of pavement and it weighed 268 pounds per square yard (thickness 2").

The original pavement was badly broken up and it was necessary to replace 4,652 square yards of old pavement, approximately 9 per cent of the original area. This highway is on U. S. Route 20 and carries an average traffic around 2,000 vehicles and the original width of 16 feet was inadequate. The resurfaced pavement today is in good shape. While a few cracks have come through the macadam, there is a tendency to heal up during the summer weather. No base failures have developed. However, at this time, it is noticed that the macadam is drying up on top with a slight tendency to ravel or shed. This may be caused by using a slowly evaporating liquefier which has lowered the penetration (also the melting point) of the asphalt and caused it to collect at the bottom of the pavement. It probably will be necessary to surface treat this road in 1933. Such surface treatment is estimated to cost about \$500 per mile.

Attached is a supplement showing in tabular form the maintenance costs per mile of pavement only on this project from the time of its construction in 1918 up to and including 1931, together with the traffic census for each year beginning in 1921 up to date.

Road F (S. H. 5543, 5544, 5607 and 5608) Machias-Hindsdale

These highways are located on a tourist route between Olean, N.Y. and Buffalo, N. Y. The concrete pavements were constructed between 1916 and 1920. They were all of the 1-1 $\frac{1}{2}$ -3 mix with uniform depth of 6 inches. The width of the old concrete was 16 feet and the subsoil is gravel and clay. Due to a traffic increase from 812 vehicles in 1924 to 2,129 vehicles in 1931 and due also to the structural condition of the old pavement, it was decided to resurface these highways, having an aggregate of 18.3 miles in length, in 1929. The project contained 164,000 square yards of M.M., Type 3; total cost was \$193,000 or an average of \$11,100 per mile. It required 4,700 square yards of concrete for patching the old pavement which is equivalent to 3 per cent of the original pavement area. The average completed depth of the resurfacing was 2.36 inches; the average weight was 276 pounds per square yard and the cost per square yard of macadam was only \$0.94.

The proportions of the respective aggregates used in the bottom and top mix and the size of aggregates are the same as those listed on Road E.

An examination of the surface of this pavement indicates that the asphalt has separated somewhat from the stone in the upper portion of the resurfacing and collected at the bottom. This has left the top stone dry with very little adhesion (although still rather dark in appearance), with a tendency to ravel. It became necessary in 1932 to surface treat the pavement to prevent ravelling and possible disintegration. The surface treatment consisted of the application of 0.18 of a gallon per square yard, using asphalt cutback, stone chips and thoroughly rolling. This seems to have restored the original appearance as well as the texture of the pavement and, at the present time, it is in very good condition.

Attached as a supplement I have shown in tabular form the maintenance cost per

mile on pavement only and the traffic census (12-hour day count) on S. H. 5607 and S. H. 5543. These are typical costs and traffic counts for the entire stretch embraced in the contract.

It is impossible to give an exact formula to be used as a guide in determining the particular time a concrete road should be resurfaced. Generally, it cannot be determined from the purely economic standpoint but depends more upon the physical, structural or possibly chemical condition of the pavement itself. The concrete pavements resurfaced were considerably scaled, with incipient disintegration in evidence over limited areas and usually the concrete has an extremely dead-white or chalky appearance. Also, the character of sound when the concrete is struck with a hammer will indicate whether it is dead or not. In at least two instances, of the first four above cited, I am satisfied that had we deferred resurfacing even another year the old pavement would probably have been beyond any salvage value. The benefits of the added depth of resurfacing are numerous but among the more important is the exclusion of moisture from entrance into the concrete where the hot mix type is used. The hot mix type also has considerable resiliency and materially lessens impact shocks on the pavement. No doubt it also adds somewhat to the strength of the pavement, although I do not believe that latter is a very large factor in its efficacy.

Due to causes beyond the realm of highway construction, reconstruction and resurfacing, New York State extensively revised its previous specifications covering the construction of so-called Mixing Method, old Type 4. From an engineering standpoint we felt that some beneficial changes might be made in the gradation of the stone used in the cold mix and a change in type of liquefier used. Also certain plant requirements were necessary

to insure more rigid control of the mix. The liquefier now required by our specifications, is generally of two grades, known as Naphtha A (light) and Naphtha B (heavy). Naphtha A volatilizes or passes off rapidly and for this reason we believe that its use does not tend to lower the penetration or melting point of the remaining asphalt, thus insuring a more stable product or at least a product of longer life, than the old specifications seemed to provide. However, I do not feel that the uncertainty of behavior of asphalts on account of solvent used is limited to the so-called cold mix. An extended observation of old penetration asphalts, applied heated, indicates that too much asphalt had been used or that too little rolling had been done. Later compaction by traffic has displaced the asphalt, forcing it to come to the top of the pavement and causing fat spots.

As to whether hot mix or cold mix, discussed above, is more desirable, I can only say that the cold mix appears to offer more resistance to skidding than the hot mix. However, I believe that provision may be made in the aggregate used for top course of the hot mix type which will reduce to a minimum the hazards alleged to be due to slippery pavement. Experimentally, on a limited scale, I have slightly modified the aggregates in the top course (particularly on Road D, discussed above) and the engineer in charge of maintenance informs me there is practically no tendency to skid on this modified top during wet weather. I recommend that the question of gradation of aggregate in the top course (Hot Mix) be given further study.

As a result of our experience since 1926, in connection with sizes of aggregate to be used in bituminous macadam M.M., Type 3, we have used very extensively in 1932 the following quantities and gradations of bottom and top course aggregates:

	Stone	Liquefier	Asphalt	Hydrated Mineral	
				Lime	Filler
Bottom Course . . .	90.9%	1 ½ gal. to ton	4.6%	0.5%	4%
Top Course	84.0%	2 gal. to ton	6.5%	0.5%	9%
<i>Stone Sizes</i>					
Bottom Course	20% of #1	—retained ¼" and passing ⅝" square holes			
	80% of #2	—retained ⅝" and passing 1" square holes			
Top Course	55% of #1				
	45% of #1A	—retained ⅛" and passing ¼" square holes			

The above gradation results in a fairly tight or close mix in the top surface of the pavement. We are trying to obtain as tight a mix as possible and still retain non-skid qualities to the greatest possible extent. The above mix is slightly open and to prevent the entrance of moisture into and through the top course we specify the application of a top dressing of clean sand or grit. Ninety per cent of this grit shall pass a No. 14 mesh laboratory sieve and 75 per cent of it shall be retained on a No. 48 mesh sieve. It shall be uniformly spread on the finished pavement at the rate of approximately 6-8 pounds per square yard of pavement, within 24 hours after the fine mix has been placed and rolled. This top dressing is moved about with brooms and finds its way down into the exposed voids in the pavement and renders the top course practically 100 per cent moisture-proof.

I mention the precaution in the above paragraph as there seems to be two schools of thought with respect to this important feature. Some advocates of this type of pavement claim that the water should pass through it and be allowed to collect on the concrete underneath and then seep out at the side. With this suggestion I cannot agree. Water is the enemy of asphalt and practically all other road building materials including concrete and as such should be excluded wherever practicable from such mix.

For some years past the criticism against macadam pavements in New York State, and I presume in other States, has been that they are too slippery, too rough or uneven and afford no color contrast to aid night driving. Roughness of pavement is due to poor workmanship on the pavement itself. There seems to have been a common tendency on the part of the engineer, whenever macadam is specified to feel that the limiting requirements contained in the specifications, may be stretched almost to the breaking point. Not enough care has been given to the preparation of subgrade and bottom course, with the thought in mind that all irregularities might be removed in the top course. This is a serious and grievous error and has been corrected to a large extent in New York by a requirement that the surface shall be tested with a 16-foot straight-edge, laid parallel with

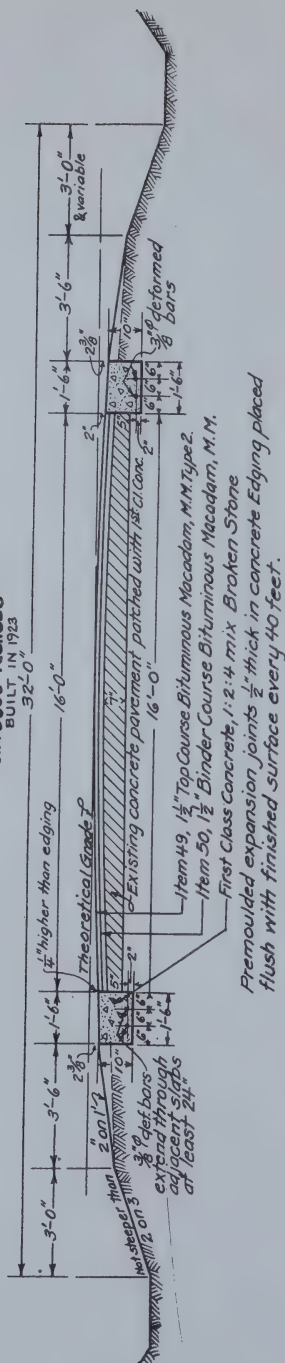
the center line of the road upon any portion of the surface and any variations from a true profile exceeding $\frac{1}{4}$ -inch shall be eliminated or the pavement relaid. The same requirement applies to bituminous macadam M.M., Type 1, and Type 2. While this may seem like a rigid requirement, I feel that it must be adhered to.

Of course, there has been great difficulty in meeting these requirements as they require a very skilled type of workman to accomplish the results and they slow up the work. There is a marked trend, therefore, to the use of a mechanical finishing machine.

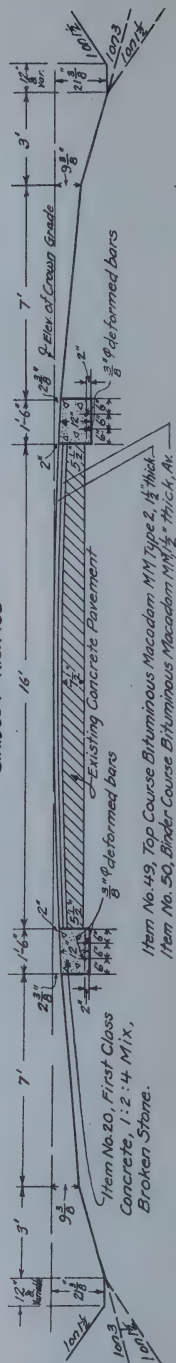
Two types of machine have been used. One is a modification and adaptation of the concrete finishing machine which is so familiar to all highway engineers. The other is a new type of machine which spreads, smooths and rolls the mixed material. At this point I want it thoroughly understood that I am not advocating any particular type of machine but I cannot refrain from commenting on this new machine as it produces a very smooth pavement and I believe will overcome the most serious objections the public now seems to have to macadam pavements.

This machine accomplishes the same functions and operations as the finishing machines used on concrete pavement, but it requires no side forms on which to travel. It is built in a 10-foot width so that it may be used on the conventional 10-foot lanes of pavement usually constructed in New York State and will allow traffic to use the other lane. The hopper near the front of the machine receives the mixed material from trucks and at the bottom of it is a revolving shaft provided with paddles which break up the lumps and insure a uniform distribution of material for the full 10-foot width of operation. Immediately back of the hopper discharge there is a screed shaped to the crown of the pavement which may be adjusted for various depths. The screed operates laterally in a similar manner to the screed on a concrete finishing machine but the forward side of the screed is provided with teeth similar in outline to those used on an ordinary cutting bar of a mowing machine. This action really saws the material off to a given height or depth and, due to a system of leverage adopted for guiding and

ROAD A
FARNHAM-IRVING
S.H 5600 RC.1358
BUILT IN 1923



ROAD B
TYPICAL SECTION
S.H. 5634 ~ R.C. 1458



supporting the machine, the resulting surface is as near smooth as anything we have so far witnessed on work of this character. The machine is also equipped with rollers located just back of the screed, which provide traction for propelling it along the pavement and a limited amount of compaction and consolidation. The operation, of course, has to be followed by the usual rolling with either 8 or 10-ton rollers which are commonly used in work of this character. The speed of the machine is variable and the common limits are from 10 to 15 feet per minute. From this the capacity of the machine may be determined.

This paper is not for the purpose of selling machinery, but the resulting pavement obtained by the use of such machine certainly overcomes the chief objections to macadam construction, namely, lack of smoothness of pavement. We have not as yet required the use of a machine in our specifications. We have, however, permitted and encourage its use in order to obtain a proper riding surface for the traveling public.

Time permits only a casual reference to the new family of asphalts known as E—Emulsions. We have only constructed a limited mileage of Emulsion Penetration Macadam pavement. The Emulsion Penetration jobs are smoother than any of the hot penetration pavements; they have a non-skid surface; they have a very dense structure with minimum voids; they require less asphalt than the hot penetration type and they are easier to build than the hot penetration type. They have rendered very satisfactory service up to date and I believe their use will expand in the future.

During the present year there were built in the State about 465 miles of so-called Road-mix bituminous surface, in which we used both the Emulsion and Cutback Asphalts. The results obtained were excellent and the cost of the pavement averaged only about 40 cents per square yard. This type of pavement, in my opinion, has great possibilities, prin-

cipally on account of its low cost, the use of local materials and the speed at which it may be constructed. It seems to me that this type of pavement is admirably adapted for use on a large mileage of as yet unimproved highways serving the rural and suburban population and functioning as feeders to State Trunk Lines.

In conclusion may I say that more asphalt pavements in New York State have been ruined by too many applications of surface treatment than by too few applications of surface treatment. These excess applications, together with the old practice of flushing the top of the pavement with asphalt, have been responsible to a very large extent for the so-called slippery pavement of the asphaltic type.

This situation is very unfortunate from the standpoint of the traveling public and the asphalt industry. The public demands and is entitled to receive safe, convenient and economical transportation from the hands of the highway building industry. The demand for smooth pavement has been partly satisfied by the advent of the finishing machine and can be completely satisfied when the use of a finishing machine is specified on all mixed types of macadam pavement. The demand for non-skid types of pavement is being satisfied by intelligent maintenance and construction methods.

I also wish to repeat here a statement I recently made before the Association of Highway Officials of the North Atlantic States to the effect that there is no object in carrying laboratory research to such a refinement that the benefits are constantly lost by a lack of refinement in construction methods. From the evidence adduced the question of rough pavement and of non-skid surfaces are primarily a construction activity. It would seem, therefore, that additional concentration should be made on these features of the asphalt industry which will not only be beneficial to it but will be of far greater benefit to the traveling public.

ASPHALT PAVING CONFERENCE, 1932

ROAD A (S. H. 5600)

<i>Maintenance Cost on Pavement Only</i>			<i>Traffic Census</i> <i>12 hr. day count</i>
1918	\$ 225.30 for 2.11 miles =	\$107.00 per mile	
1919	26.50	13.00 " "	
1920	227.87	108.00 " "	
1921	458.26	217.00 " "	
1922	1818.06	860.00 " "	1881
1923	being reconstructed (2.11 Mi.)		2667
1924	41.00	19.00 " "	3529
1925	40.00	19.00 " "	4625
1926	160.85	76.00 " "	3576
1927	1453.06	688.00 " "	4693
1928	305.17	144.00 " "	4806
1929	252.22	120.00 " "	5886
1930	356.10	169.00 " "	6546
1931	554.25	262.00 " "	3999*

NOTE—Charges for 1930 and 1931 also include maintenance on 11-foot strip of concrete 1.30 miles long, built in 1928.

* Southwestern Boulevard open to traffic.

ROAD B (S. H. 5634)

<i>Maintenance Cost on Pavement Only</i>			<i>Traffic Census</i> <i>12 hr. day count</i>
1922	\$817.97 for 5.28 miles =	\$154.00 per mile	1554
1923	950.30	181.00 " "	2620
1924	698.62	132.00 " "	3918
1925	being reconstructed (5.28 miles)		
1926	83.60	16.00 " "	3783
1927	664.08	126.00 " "	5114
1928	604.19	115.00 " "	5073
1929	514.59	97.00 " "	6163
1930	381.31	72.00 " "	5528
1931	379.78	72.00 " "	3789*

NOTE—1930 and 1931 include maintenance cost on 11-foot strip of concrete constructed in 1928.

* Southwestern Boulevard open to traffic.

ROAD C (S. H. 5546)

<i>Maintenance Cost on Pavement Only</i>			<i>Traffic Census</i> <i>12 hr. day count</i>
1916	\$ 317.15 for 4.48 miles =	\$ 71.00 per mile	
1917	150.64	33.00 " "	
1918	815.68	182.00 " "	
1919	6.00	2.00 " "	
1920	631.25	141.00 " "	
1921	418.07	93.00 " "	
1922	117.94	26.00 " "	2312
1923	1219.17	272.00 " "	2983
1924	899.49	201.00 " "	3918
1925	1065.12	238 " "	4078
1926	Entire length being reconstructed		3783
1927	Entire length being reconstructed		No count
1928	547.93	122.00 " "	" "
1929	295.30	66.00 " "	" "
1930	398.20	89.00 " "	7330
1931	380.50	85.00 " "	5341*

NOTE—The charges from 1928-1931 include the maintenance of the 10-foot strip of concrete.

* Southwestern Boulevard open to traffic.

ELMER C. LAWTON

ROAD D (C. H. 1380-A—9028)

<i>Maintenance Cost on Pavement Only</i>					<i>Traffic Census</i> 12 hr. day count
1921	Maintained by County; no figures available.				
1922	"	"	"	"	"
1923	"	"	"	"	"
1924	"	"	"	"	"
1925	"	"	"	"	"
1926	"	"	"	"	"
1927	Being reconstructed—entire road				
1928	Being reconstructed—entire road				
1929	\$	0.00	for 9.78 miles	= \$ 0.00 per mile	2098
1930	366.39			37.00 " "	2402
1931	176.50			18.00 " "	2402

ROAD E (C. H. 1066)

<i>Maintenance Cost on Pavement Only</i>					<i>Traffic Census</i> <i>12-hr. day count</i>	
1918	\$113.40	on 6.56 miles	(no separations to types)	\$ 17. per Mi.		
1919	173.25	on 6.56 miles	(no separations to types)	26. per Mi.		
1920	146.30	on 4.61 miles	Concrete pavement	32. per Mi.		
1921	100.75	on 4.61 miles	Concrete pavement	22. per Mi.	401	
1922	814.33	on 4.61 miles	Concrete pavement	} 194. per Mi.		
	109.60	on 0.15 miles	Stone block pavt.			
1923	523.38	on 4.61 miles	Concrete pavement	113. per Mi.	692	
1924	724.24	+ 444.10	for surf. treat. on 4.61 Mi.	} 219. per Mi.		
			concrete pavt.			
	236.71	on 1.80 miles	brick pavement	} 452. per Mi.	870	
1925	678.63	+ 2016.33	for surf. treat. on 4.61 Mi			
			concrete pavt.	} 148. per Mi.	1054	
	203.74	on 1.80 miles	brick pavement			
1926	827.15	on 4.61 miles	concrete pavement	} 727. per Mi.	1075	
	124.00	on 1.80 miles	brick pavement			
1927	947.82	+ 2404.46	for surf. treat. on 4.61 Mi.	} 727. per Mi.	1543	
			concrete pavt.			
	None on brick pavement					
1928	5.16	miles reconstructed with M.M.,	Type 3			
1929	5.16	miles reconstructed with M.M.,	Type 3			
1930	287.72	on 5.16 miles	M.M., Type 3	56. per Mi.	1698	
1931	320.65	on 5.16 miles	M.M., Type 3	62. per Mi.	2016	

ROAD F (S. H. 5607)

<i>Maintenance Cost on Pavement Only</i>					<i>Traffic Census</i> 12-hr. day count
1921	\$175.78	for 4.72 miles	=	\$ 37. per Mi.	
1922	147.70			31. per Mi.	
1923	236.00			50. per Mi.	
1924	893.74			189. per Mi.	812
1925	1065.20	+ 1964.53	for surface treatment =		
			226 + 416 =	642. per Mi.	795
1926	847.03	+ 1743.91	for surface treatment =		
			179 + 370 =	560. per Mi.	885
1927	589.03			125. per Mi.	1248
1928	962.44	+ 2859.32	for surface treatment =		
			204 + 605 =	809. per Mi.	1558
1929	Entire length reconstructed with M.M. Type 3				
1930	58.06			12. per Mi.	2088
1931	103.25			22. per Mi.	2129

ASPHALT PAVING CONFERENCE, 1932

ROAD F (S. H. 5543)

<i>Maintenance Cost on Pavement Only</i>		<i>Traffic Census 12-hr. day count</i>	
1922	\$282.72 for 6.97 miles	\$ 40. per Mi.	
1923	355.75	51. per Mi.	490
1924	385.00	55. per Mi.	633
1925	1778.57 + 1419.60 for surface treatment =		
	255 + 203 =	458. per Mi.	753
1926	1022.29 + 544.18 for surface treatment =		
	146 + 78 =	224. per Mi.	742
1927	972.27	140. per Mi.	No count
1928	2361.65 + 2112.27 for surface treatment =		
	339 + 304 =	643. per Mi.	972
1929	6.13 miles reconstructed with M.M., Type 3		
1930	13.56 for 6.13 miles =	2. per Mi.	1402
1931	765.75 for 6.13 miles =	125. per Mi.	1458

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